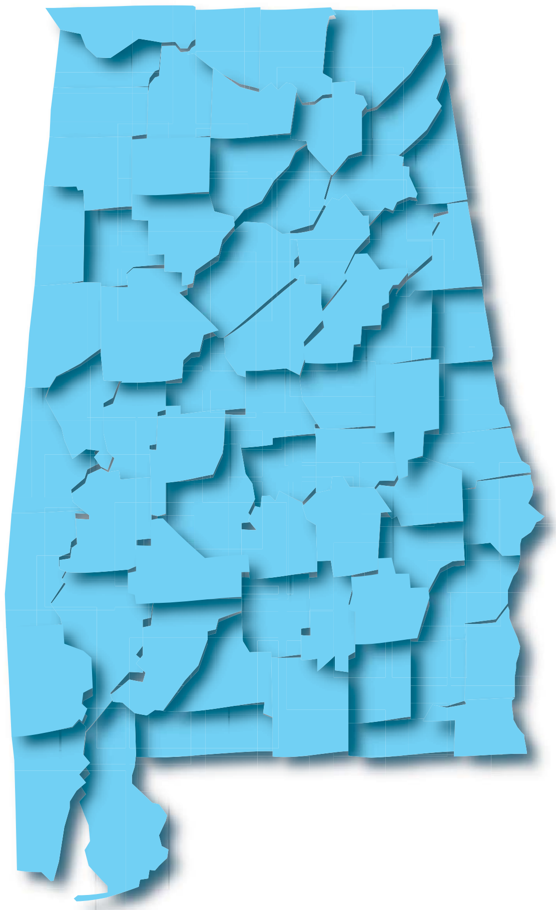
An Assessment of Wood-Based Syngas Potential for Use in Combined Cycle Power Plants in Alabama



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Executive Summary

Renewable energy is an area of growing interest in the United States. A combination of recent political and economic events has brought the subject of domestic renewable energy into the center of both the public and political arenas. Rising prices for fossil fuels, and in particular natural gas, have been cause to re-evaluate various renewable energy sources that have previously been considered economically unviable. At the same time, continuing turmoil and political instability in international oil producing regions has called into question the potential ramifications of the United State's continuing dependence on these regions for a major portion of its energy supply. Finally, the nation's concern for maintaining a clean and healthy environment has provided a continuing impetus to search for alternatives to fossil fuels and their inherent environmental problems.

Among the choices for renewable energy sources are wind, solar, hydro, geothermal, and biomass. In Alabama there are limited opportunities for any of these alternatives other than biomass. Fortunately, the State is blessed with abundant biomass resources, primarily in the form of trees. Over 70% of the land area of Alabama is covered with forests, providing the State with an enormous and growing source of wood. Although this wood is used primarily for the production of pulp, paper and wood products, there are significant volumes of woody biomass that could be utilized for the production of energy. With the supplies of timber exceeding market demand in many areas, timber prices have fallen. There is a real need to develop new markets for timber and wood by-products. Biomass energy has a real potential to provide a part of that market solution.

There are several current technologies available for the conversion of biomass to energy, and new ones being researched, developed, and refined. One technology that appears to have considerable future promise is the gasification of wood. Gasification, which is a form of pyrolysis, has been available on a small scale since World War II. However, gasification on a large scale has only recently been pursued and the technology is still being refined. Through this technology, however, woody biomass can be converted to a synthetic gas, which could potentially be substituted for natural gas. This synthetic gas, or syngas, has approximately half the energy value of natural gas, but can either be substituted or blended with its fossil fuel counterpart. Syngas could be used directly as a source of thermal energy, or could be converted to electrical energy.

This report has focused on the opportunity to convert a portion of Alabama's woody biomass to electricity on a large scale. This opportunity is interesting in that a growing proportion of electricity in both the United States and Alabama is being generated from natural gas. Much of the new electrical generating capacity developed and planned in recent years has been either combined cycle or simple cycle electrical generating plants, which are smaller in scale than conventional power plants, and utilize natural gas as their primary fuel source.

The concept for utilizing wood-based syngas in this application would be to locate a large gasification operation in close proximity to a combined cycle power plant, where the syngas could be blended with natural gas and used to produce electricity. In Alabama there are approximately twenty combined cycle or simple cycle power plants that are either operating, under construction, or planned.

As a major part of the study effort, three locations in Alabama were identified as potentially suitable for the location of a plant to produce syngas for the generation of electricity. These were locations that had two or more combined cycle power plants and were thought to be in close proximity to significant volumes of available woody biomass fuels. Locations in the Decatur, Autaugaville, and Mobile areas were identified for further analysis, with particular attention to fuel availability. The analyses determined that at each of these locations there is approximately two million dry tons of woody biomass fuels potentially available within a reasonable haul distance.

The analyses considered the availability of both forest residues and wood products manufacturing residues. Forest residues consist of logging residues and cull trees that could be recovered via whole tree chipping during normal logging operations. Manufacturing residues focused primarily on bark and sawdust from primary manufacturing operations, as well as the potential for wood waste streams from secondary manufacturing operations. From a cost standpoint, secondary residues are likely the least expensive, followed by bark and sawdust, with whole tree chips from forest residues being more expensive. Not considered at this time due to price limitations were shavings, pulp chips, or roundwood.

A model syngas production operation was developed for purposes of this study. The model syngas facility would convert approximately 576,000 dry tons of woody biomass annually into syngas sufficient to produce 155 megawatts of electricity at the associated combined cycle plant. Although the model plant is approximately four times larger than any similar facility currently in operation, the plant is comprised of modular gasification units that are similar in scale to existing operations. Therefore, although the model plant is unprecedented, it is believed to be technologically viable.

The model syngas facility would require a capital investment of $96 million and would employ 92 persons. At an estimated dry fuel cost of $20 per ton and a natural gas equivalent price of $4.11 per mmBtu, this investment would yield a return on investment (ROI) of approximately 6%. This return is obviously insufficient to attract investment capital to a project of this risk level. However, it should be noted that with the addition of tax credits that are currently proposed in the Energy Bill for FY2004, the investment returns improve to approximately 19%. When the potential for income for environmental credits is considered, the returns have the potential to become very attractive. In addition, the investment returns are obviously very sensitive to natural gas prices, which are widely predicted to show further increases in the coming years. Thus, with a favorable combination of public policy and rising natural gas prices, a large-scale syngas operation could potentially represent a very attractive investment.

Alabama has the potential to be at the forefront of a large developing biomass energy industry. The significant availability of woody biomass in this State provides the potential for an abundant fuel source at reasonable cost. Favorable economic and political forces are converging that could stimulate the development of such a biomass energy industry in the near future. Large-scale gasification of wood to produce syngas for use in electrical generating plants is one promising technology that appears to have significant potential. This technology, along with other biomass energy conversion technologies, warrants further evaluation and could potentially provide multiple benefits for the economic and environmental well-being of our State.

Chapter One

Introduction

Renewable energy from biomass has been a subject of interest for many years. The nation has long understood the economic and political problems that result from dependence on foreign energy sources. Likewise, the deleterious effects on the environment that result from burning fossil fuels as our primary energy source are of increasing concern. Therefore, various clean, renewable energy sources have been studied as possibly providing solutions to these problems. However, the economics of developing these new energy sources have been an obstacle to commercial development in an environment of relatively inexpensive fossil fuel alternatives. Recent political events and rising energy prices, however, have given new emphasis to the need for efforts to examine other energy alternatives.

The State of Alabama is blessed with a large timberland base and abundant wood resources. As we consider the various options for clean, renewable energy production in the state, the possibility of utilizing some form of our forest resources for that purpose becomes an obvious consideration. Other forms of clean, renewable energy, such as hydro, geothermal, or wind have very limited opportunities in Alabama. Herbaceous biomass fuels, such as agriculture residues or energy crops, may have some potential, but face challenging economics and limited applicability. Utilizing the woody biomass from Alabama's vast forest resources as a possible energy source seems to offer an obvious fit with the circumstances at hand.

There are many possible ways to convert biomass, including woody biomass, into energy. Alternative technologies such as direct combustion, cofiring with fossil fuels, gasification, reforming into various biofuels, and other opportunities have all been explored and continue to be developed. Ultimately, the solution may be a mix of several of these technologies as part of an overall energy strategy. The intent of this report is to investigate the large-scale gasification of woody biomass as one technology which offers significant promise. More specifically, the report examines gasification with the intent to supply the resultant syngas as a fuel for generating electric power in combined cycle power plants.

The evolution and deregulation of the electric utility industry has resulted in a growing role for independent power producers in the production of the nation's electricity. A favored technology during this period of both existing electric utilities and independent power producers has been the combined cycle power production facilities, and to a lesser extent, the simple cycle power plants. These plants, which primarily use natural gas, have both cost efficiencies and environmental benefits when compared to conventional coal-fired power plants. Consequently, over 600 such facilities have been proposed across the United States in recent years. Alabama has participated strongly in this national trend, with approximately twenty combined cycle operations either operating or planned.

This report intends to preliminarily examine the feasibility of large-scale gasification operations within the state that would supply syngas to existing or planned combined cycle power plants as a substitute for natural gas. The potential benefits of these operations would be improved markets for various forms of woody biomass, a reduction in our dependence on imported energy, and improved environmental quality by reducing greenhouse gases that result from burning fossil fuels. The study's emphasis is on identifying and quantifying the potential sources and volumes of woody biomass that might be economically available for large-scale gasification. The study further attempts to identify three viable locations within the state for such operations based on available fuel resources and the presence of combined cycle generating facilities. Finally, the economics of the proposed gasification projects are evaluated under several alternative scenarios to determine the investment potential of the project and the effect of changes in key pricing and cost variables.

Chapter Two

Combined Cycle Power Plants

The electric utility industry in the United States is an industry in transition. In recent years, the industry has come under increasing scrutiny from legislators, regulators and economists. The new focus has been on questioning the long-held assumption that electric utility companies were natural monopolies and deserved protection against competition. Increasingly, a more competitive operating environment is being favored. Electric utilities no longer enjoy operating a protected industry where they could be the sole company that generates, transmits, and distributes electric power. Today new entrants are being allowed into the industry, particularly in the area of power generation.

The door was opened for major industry changes with the enactment of the Public Utility Regulatory Policies Act (PURPA) in 1978. This legislation made it possible for new operators to enter the field of electric power generation. No longer was this the sole domain of regulated utilities. Non-utilities were permitted to generate electric power and sell it in the wholesale market. The act stipulated that power generated by non-utility producers under certain criteria could be sold to the utilities, and that they were further obligated to purchase such power at their avoided cost.

The Energy Policy Act of 1992 (EPACT) further opened access to the transmission network for non-utility power producers. Furthermore, EPACT reversed some of the restrictions of the Public Utility Holding Company Act (PUHCA) of 1935, allowing utilities to compete more broadly across geographical lines. PUHCA had earlier forced interstate utility companies to consolidate and operate within strict geographical boundaries. The new law opened the industry to wider competition, both by reducing geographical barriers and by facilitating the entry of non-utility power generators. Further refining the competitive environment, the federal energy Regulatory Commission issued two orders in 1996. Orders 888 and 889 opened transmission access to non-utilities, and required that utilities share information about available transmission capacity with non-utility companies. The Orders further separated the transmission function from the generating and marketing functions of electric utilities.

With the changes in the regulatory and operating environments for the industry have come corresponding adjustments by the utility companies themselves. In preparation for a more competitive environment, the utilities have been engaged in massive campaigns to reduce operation and maintenance expenses, cut payrolls, and streamline corporate structures. In addition, there has been significant merger, acquisition and divestiture within the industry. In some cases, diversification into other businesses has also been a result. One result of these changes has been the emergence of the non-utilities as an increasingly important factor in the generation of electric power.

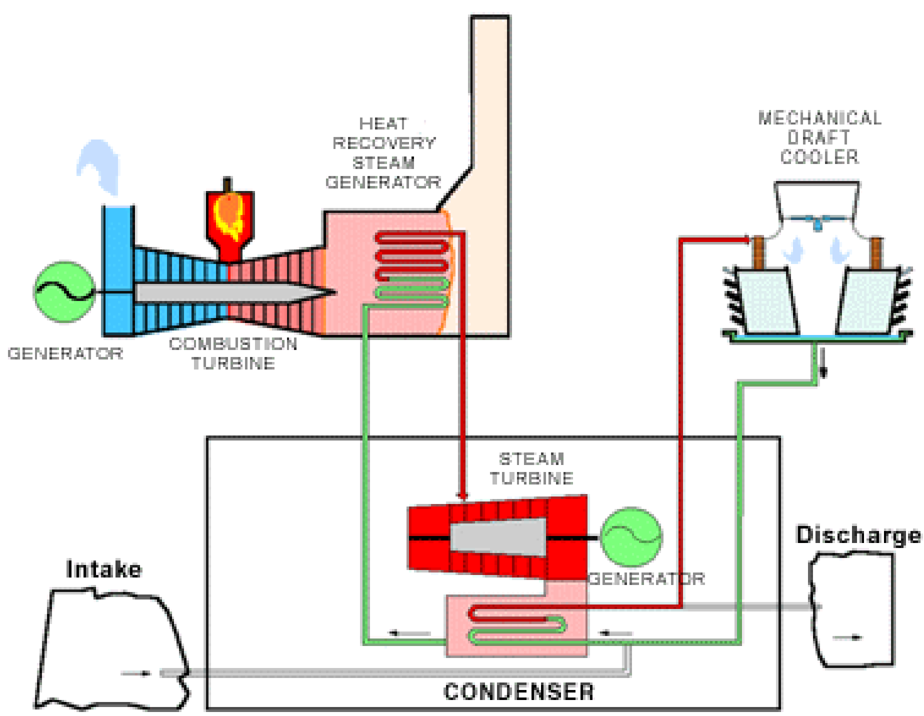
The non-utility companies have both acquired power generating assets from utilities who have chosen to divest themselves of these facilities, and they have been heavily involved in investing in the construction of new facilities. The data shows that over the last ten years, there has been more electric power generating capacity added by non-utility companies than by the traditional investor-owned utility companies. Among the favored power-generating technologies attracted investment capital is the use of natural gas in both combined cycle and simple cycle power-generating, but primarily combined cycle operations. These facilities have many advantages over conventional coal, oil and nuclear facilities. Capital and operating costs are lower. Permitting and construction times for new facilities are much shorter. A typically-scaled combined cycle power plant can be built for a couple hundred million dollars, and brought on line in approximately two years. This represents a fraction of the capital and time required to construct a large-scale conventional coal or nuclear facility. Additionally, the potential environmental impacts of natural gas-fueled power generation are greatly reduced.

Combined Cycle Power Plants

Many combined cycle power plants, fueled by natural gas, have been built across the United States in the last few years. More are planned, as the industry increasingly moves towards natural gas as a preferred fuel for generating electric power. The advantages of this technology are distinct in that a combined cycle power plant is forty percent more fuel-efficient than older fossil-fueled electric generating facilities. In addition, modern, natural gas fueled combined cycle power plants produce approximately 90% fewer air emissions than a comparable coal-burning operation.

Combined cycle power plants generate electricity in two separate cycles. In the initial cycle, natural gas and compressed air from a combustion turbine are blended and burned in a combustion chamber. The energy released during this combustion is used to turn a turbine, which

FIGURE 1: COMBINED CYCLE POWER PLANTS



in turn drives a generator to produce electricity. Exhaust gases are captured from the combustion turbines and are routed through a heat recovery system. This recovered heat, which would otherwise be wasted, is then used to convert water into steam. In the second cycle, the steam generated from the heat recovery system is used in a steam turbine. Electricity is made from an electric generator which is driven by this steam turbine. Thus, electricity is generated in both cycles, making this technology very efficient when compared to most conventional alternatives. Figure 1 displays a simplified diagram of the combined cycle technology.

Simple Cycle Power Plants

The simple cycle power plant technology is essentially the first stage of the combined cycle plant, without the heat recovery feature. The simple cycle plant consists of a gas compressor, fuel combustors, and a gas expansion turbine. Air is compressed in the gas compressor. Energy is added to the compressed air by combusting liquid or gaseous fuel in the combustor. The hot, compressed air is expanded through a gas turbine, which drives both the compressor and an electric power generator.

A number of these plants have also been built, and more are proposed. While this technology is not as efficient as the combined cycle model, it is cheaper to construct and has certain operational advantages. Simple cycle power plants are used primarily to provide either "peaking" or standby service. The big advantage of the gas-fired simple cycle plant is that it can be started up quickly, bringing electricity on-line as needed.

While both combined cycle and simple cycle power plants have certain advantages in their fuel efficiency, capital cost, ease of operation, and environmental impact, they do have the disadvantage of utilizing a comparatively high-cost fuel. The cost of natural gas, which is the fuel of choice for these operations, is both expensive and volatile. Depending on geographical area, natural gas prices to electric utilities have doubled and even tripled in some cases.

Simple and Combined Cycle Plants in Alabama

The trend toward natural gas-fired simple and combined cycle plants for electric generation has not by-passed Alabama. There are currently eighteen such facilities in Alabama that either are operating, under construction, or have applied for air emissions permits. All of these projects have been initiated since 1998. These investments have been heavily weighted toward the combined cycle technology; however, two simple cycle operations are also included on the list. Geographically, the operations are distributed across the state, but are naturally located in proximity to both a major natural gas pipeline and required electric transmission lines. The eighteen operating and proposed facilities are expected to have a combined electricity generating capacity slightly in excess of 15,000 MW. Ownership of these operations is a mix of both investor-owned utilities, electric utility cooperatives, and non-utility companies. Table 1 displays active natural gas-fueled combined cycle and simple cycle power plant projects in Alabama.

TABLE 1: COMBINED & SIMPLE CYCLE POWER PLANTS IN ALABAMA

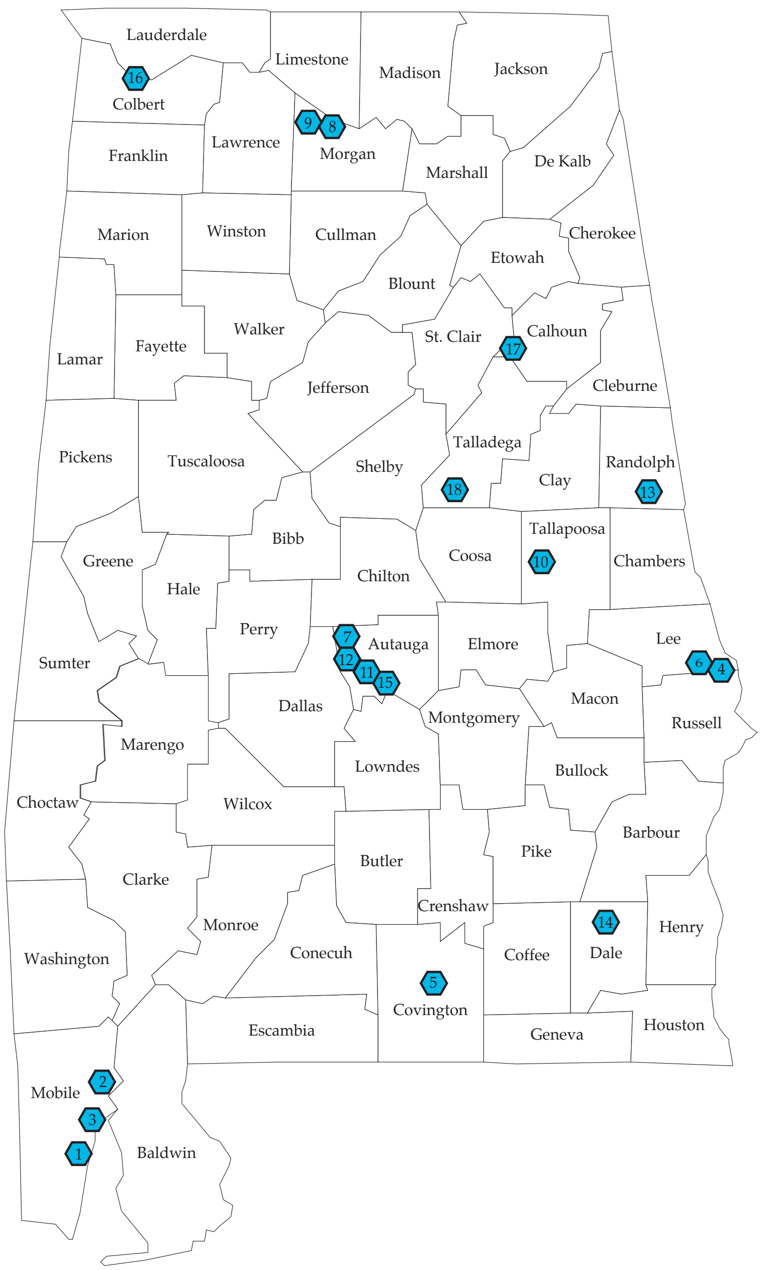
Plant	**County**	**Type**	**Approx. Size** (MW)	**Nat. Gas Consump.** (SCFM)
Ala. Power - Theodore	Mobile	Combined Cycle	210	19,950
Ala. Power - Plant Barry	Mobile	Combined Cycle	1,000	95,000
Mobile Energy - Hog Bayou	Mobile	Combined Cycle	220	20,900
SEEDCO	Lee	Simple Cycle	100	9,500
Ala. Elec. Coop. - McWilliams	Covington	Combined Cycle	496	47,120
Georgia Power - Goat Rock	Lee	Combined Cycle	2,280	216,600
Tenaska Ala. Partners	Autauga	Combined Cycle	850	80,750
Calpine - Decatur Energy Ctr.	Morgan	Combined Cycle	700	66,500
Calpine - Morgan Energy Ctr.	Morgan	Combined Cycle	700	66,500
Calpine - Hillabee Energy Ctr.	Tallapoosa	Combined Cycle	707	67,165
Tenaska Ala. II Partners	Autauga	Combined Cycle	850	80,750
SEEC	Randolph	Combined Cycle	1,500	142,500
Ala. Power - Autaugaville	Autauga	Combined Cycle	1,260	119,700
Kinetic - FPL	Calhoun	Simple Cycle	628	59,660
Tenaska Ala. IV Partners	Talladega	Combined Cycle	1,160	110,200
Duke Energy Autauga, L.L.C.	Autauga	Combined Cycle	630	59,850
Duke Energy Dale, L.L.C.	Dale	Combined Cycle	630	59,850
Barton Shoals Energy	Colbert	Combined Cycle	1,200	114,000
			15,121	1,436,495

These facilities will add substantial generating capacity to Alabama's electric infrastructure and will also represent a very significant consuming industry for natural gas. Although unlikely, if all of the above projects come to fruition, the generating capacity from natural gas burning facilities in Alabama will exceed that of coal.

Figure 2 provides a map which displays the active combined cycle and simple cycle natural gas-fired electric generating operations in Alabama.

The proliferation of natural gas-fired electric generating facilities presents an opportunity for the use of synthetic gas (syngas) as a substitute for natural gas. Syngas can be produced from biomass through gasification technologies, including various forms of woody biomass. Chapter 3 discusses the potential for generating syngas from biomass for possible use in generating electricity.

FIGURE 2: ALABAMA COMBINED CYCLE & SIMPLE CYCLE POWER PLANTS



Key

1 Ala. Power - Theodore Cogen
2 Ala. Power - Plant Barry
3 Mobile Energy - Hog Bayou
4 SEEDCO
5 Ala. Electric Coop. - McWilliams
6 Georgia Power - Goat Rock
7 Tenaska Alabama Partners
8 Calpine - Decatur
9 Calpine - Morgan
10 Calpine - Hillabee
11 Duke Energy Autauga, LLC
12 Tenaska Alabama II Partners
13 SEEC
14 Duke Energy Dale, LLC
15 Ala. Power - Autaugaville
16 Barton Shoals Energy
17 Kinetic - FPL
18 Tenaska Alabama IV Partners

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Chapter Three

Woody Biomass Gasification

The gasification of woody biomass is a century-old technology that flourished before and during World War II. The technology was largely abandoned after the war due to the ready availability of liquid fuels at reasonable cost. The interest in gasification technology has undergone many ups and downs in the intervening period. Just like the entire subject area of biomass energy, interest in biomass gasification has peaked and ebbed with the availability and price of oil and other fossil fuels. Today there is renewed interest in biomass gasification due to increased environmental concerns associated with fossil fuels and to the uncertainty over the availability and price of those fuels.

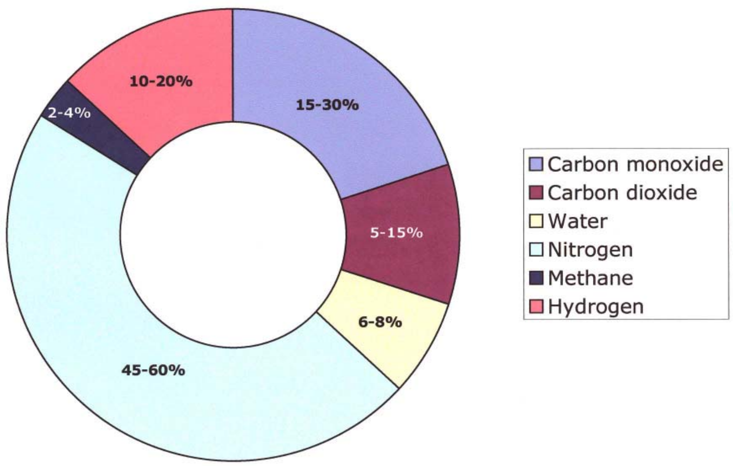
While biomass gasification is an old technology, it is also a developing technology, since it was never fully embraced on a large commercial scale. Historically, most of the emphasis has been placed on small-scale gasifiers. Many systems have been designed and tested over the years. Over the last two decades, there has been increasing interest and research in the technology for large-scale gasifiers, particularly for heat and power generation. Developmental research work in increasing conversion efficiencies, product output control, increasing operations scale, efficient syngas cleaning technologies, and other areas is ongoing. Although significant progress has been made, the viability of large-scale commercial gasification operations will ultimately be dependent on the further development of these technological aspects, particularly as they impact operational economics.

Gasification is a form of pyrolysis, in which solid biomass is converted into gas through a thermochemical reaction. Through pyrolysis, solid biomass can be converted to liquid fuel by heating the biomass in the absence of oxygen, or partially combusting it in a limited oxygen supply. What is normally produced is a hydrocarbon rich gas mixture, an oil-like liquid, and a carbon rich solid residue. The carbon rich solid is charcoal, the liquid is bio-oil, and the gas is called producer gas, synthetic gas, or syngas. In the gasification process, pyrolysis is carried out with the introduction of more air and at higher temperatures, generally in the range of 600-1000°C. The process thus modified tends to optimize the production of gas.

The gas produced from biomass gasification, or syngas, is a mixture of carbon monoxide, hydrogen, and methane, together with carbon dioxide and nitrogen. Generally speaking, the process also produces solid char and tars that would be liquid under normal ambient conditions. The precise proportions of these various constituents varies widely and will depend upon the specific fuel source and operating conditions for conversion. The energy content of the syngas depends significantly on the approach used to supply heat to drive the gasification reactions. Most designs use oxygen as an oxidizing agent, either in air or in its separated form. Heat is generated by partially combusting the biomass feedstock. In air-blown gasification, nitrogen in the air dilutes the syngas product, so that a low-energy gas results. This low-energy syngas can be used where the heat content of the gas is not critical.

This type of syngas is generally not an appropriate feedstock for the synthesis of liquid fuels nor is it suitable for use as fuel for gas turbines, which is of primary interest here. Low-energy syngas is a more versatile fuel than the original biomass, however, and can be burned to produce process heat or steam. It has also been successfully used in internal combustion engines, most notably during World War II. Figure 3 displays the approximate breakdown of low-energy syngas components.

FIGURE 3: COMPONENTS OF LOW-ENERGY SYNGAS



Of more interest to this investigation is the production of medium-energy syngas, which has the capability of being used in gas turbines to produce electricity. The energy value of medium-energy syngas produced from woody biomass is approximately 490 Btu/scf (HHV), or about half the comparable value of 1010 Btu/scf (HHV) for natural gas. The precise energy value of this syngas will vary somewhat with the components of the gas, which again is a function of both the wood species used and the specific operating parameters of the conversion process.

Medium-energy gases can be produced using pure oxygen instead of air as the oxidizing agent to provide heat for the gasification process. By using oxygen instead of air, large volumes of nitrogen are excluded, which would become a major dilutant to the heating value of the resulting syngas (see Figure 3 above). In the absence of oxygen, medium-energy gases can be produced by pyrolosis using a reactor where heat for the gasification is provided from an external source. In these indirectly-fired gasifiers, heat is provided by using heat exchangers and circulating the hot bed material.

Both low-energy and medium-energy gasifiers have been developed and built in numerous configurations. These would include fixed bed gasifiers in both updraft or downdraft varieties. Other types would include the moving "fluidized" bed gasifiers, which utilize fluidized or entrained solids as the bed material. In addition, various types of moving grate beds have been utilized in gasifiers, as well as molten salt reactors. To date, most gasifiers have been of either the fixed bed or "fluidized" bed technologies.

Fixed bed gasifiers are most common, but are best suited to smaller scale operations. They have a stationary reaction zone which is normally supported by a grate. Biomass is normally metered from the top of the reactor. Both downdraft and updraft versions are available. Downdraft versions have been shown to be the cleaner of the two varieties in terms of particulate and tar emissions in the product. The fixed bed systems are generally easy to operate at a small scale, but difficulties are often encountered when the scale increases.

Fluidized bed gasification seems better suited to large-scale applications, and most large gasifiers built in recent years have utilized this technology. Examples of the fluidized bed systems are the bubbling fluidized bed gasifiers, the entrained bed gasifiers, and the circulating fluidized bed gasifiers. In a bubbling fluidized bed gasifier, the bed material is agitated by gases flowing through it. In an entrained bed gasifier, the solids are entrained in the gas flow at high velocities. Circulating fluidized bed gasifiers employ a system where the bed material circulates between the gasifier and a secondary vessel. Various designs are possible, with biomass fuels being fed into the top, bottom or middle of the moving bed.

The heating source for fluidized bed systems can be provided either directly or indirectly. The movement occurring in the bed material provides effective and efficient heat transfer. Syngas typically exits these systems at a high temperature, and has relatively high particulate contents due to the turbulence within the reactor. Due to the high temperatures involved, the syngas may also contain vaporized alkali salts. Tars will also be present in the gas in varying amounts depending on the specifics of the operation.

Various other gasification systems have been proposed, however, most of these have not been tested on a large scale. While some of these hold considerable promise for future development, they do not currently provide available solutions, and are thus not explored further herein.

Commercial biomass gasifiers are available in a wide range of sizes, from small, portable units, to fairly large stationary units consuming several hundred tons of fuel per day. Commercial gasifiers utilizing fossil fuels, notably coal, have been constructed on a much larger scale. Theoretically, a biomass gasifier is a fairly simple device consisting generally of a cylindrical container with space for fuel, air intake, gas exit, and a grate. The cylinder can be made of masonry or metal. The gasifier itself is generally part of a larger system which includes the gasification unit, a gas cleaning unit, and an energy converter. The energy converter is a system for combusting the gas to produce thermal energy, which in turn may be used to generate electrical energy.

One of the challenges of using syngas is the requirement to "clean" the gas prior to conversion to energy. As has been discussed, syngas is a mixture of combustible and non-combustible gases, along with tar vapor, water vapor, dust, and mineral vapors. Sulphur compounds and nitrogen compounds, although normally a very small component of medium-energy syngas, are undesirable as their condensates are pollutants and can be corrosive. Silicon oxide and iron oxide can be found in dust within the syngas, and these materials are problematic due to their abrasive nature. Tar is also present within syngas, and is one of the more difficult problems with regard to cleaning.

The level of gas cleanup required is very much dependent on the technology which will be used to convert it to energy. For combustion applications in kilns or co-firing systems, gas cleanup can be minimal. However, for applications such as the high efficiency gas turbine technology considered herein, the syngas must be cleaned fairly intensively in order to meet the required fuel quality standards. Also, if the gas is to be synthesized into liquid fuels, stringent cleanup will be required in order to achieve desired results.

Various technologies have been employed for the cleaning of syngas. Gas cleanup systems may contain several components such as cyclones, scrubbers, and filters. Each stage of such a multi-level system would remove certain contaminants. The primary contaminants of concern are particulates, alkali compounds, tars, nitrogen compounds, and sulphur compounds. Particulates are solids that are entrained in the syngas as it leaves the gasifier. Generally included in the particulate matter is inorganic ash, char, and material from the gasifier bed. Fortunately, the inorganic material in clean woody biomass is generally low, typically in the neighborhood of 1%. While these levels are much lower than many other forms of biomass fuels, they are still high enough to necessitate removal from the product. Char entrained in the syngas represents unconverted biomass. While large-scale gasifiers can obtain carbon conversion efficiencies of up to 99%, the remaining 1% in the form of char must be removed from the syngas. Fortunately, this material can be collected and re-entered into the gasification system to be subsequently converted. Particulate matter can generally be fairly easily removed by barrier filters or other conventional means.

Alkali compounds also occur in syngas and are more problematic in terms of both the potential damage to downstream conversion systems and the difficulty of removal. Sodium and potassium salts vaporize at moderate temperatures and can remain in the syngas until depositing on cooler surfaces in the system, such as turbine expansion blades. Alkali salts are also corrosive and can cause problems beyond simple deposition on system components. Typical systems for removing alkali salts involve cooling the syngas below the required condensation point to convert these contaminants to solids, where they can subsequently be removed by a variety of filtering systems. Fortunately, the alkali content of woody biomass is fairly low.

Tars are also a problematic contaminant of syngas which must be addressed. The term "tar" includes a wide variety of oxygenated aromatics that are formed in the pyrolysis step of the gasification process. Tars can also create a variety of problems in downstream applications when they condense from the syngas at cooler temperatures. Fouling of precision components and cleanup problems may result. In addition, tars can potentially deactivate certain reforming catalysts. The most common system for tar removal is condensation into aerosol droplets and then removing the droplets with technologies similar to those used for particulate matter. Cyclones, wet scrubbers and electrostatic precipitators can all be used successfully for this purpose.

Nitrogen compounds are also found in syngas, primarily in the form of ammonia. The concentrations of ammonia are normally low with most woody biomass feedstocks. However, ammonia contaminants are undesirable because they lead to the formation of NO_x emmissions when the syngas is burned. Cleanup of ammonia from syngas is therefore required in locations with strict NO_x regulations. The use of syngas, however, is more environmentally favorable with regard to NO_x emissions than direct combustion of the biomass fuel itself, since the combustion process can be much more closely controlled when utilizing syngas versus solid fuels.

Sulphur is another potential contaminant, as it can be converted to hydrogen sulfide or sulphur oxides in the gasification process. Fortunately, sulphur is present only in very low levels within woody biomass. Typically these levels are below 0.1% by weight. Nevertheless, even low levels of sulphur can be a problem as they will react unfavorably with certain catalysts. A prime example involves the conversion of syngas to methanol, wherein sulphur compounds can ruin the catalysts used in that process.

While there are many technologies available for the cleanup of various contaminants in syngas, these will not be further explored herein. It is imperative to understand, however, that gas cleanup is a highly important step in rendering syngas suitable for the application explored in this report. Gas turbine systems do not tolerate contaminants well, and the acceptability of syngas in these systems will depend on the quality and cleanliness of the gas, as well as important economic issues.

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Chapter Four

Alabama Woody Biomass Availability

The state of Alabama is blessed with abundant forest resources. Approximately 71% of the entire land area of the state is forested. These 23 million acres of forest land contain nearly 28 million cubic feet of commercial timber. Furthermore, over the last several decades, Alabama has been gaining both timberland area and timber inventory. Going forward, estimates are that timber inventories in the state are likely to continue to expand at robust rates.

Alabama's bountiful forests support a very large and diverse forest industry that contributes substantially to the State's economy. The pulp & paper, wood products, and secondary wood manufacturing industries together contributed an estimated $13.2 billion to the State's economy in 2001. These industries employ approximately 65,000 Alabamians and provide an annual payroll of $2.1 billion. The forest industry is the largest exporting sector of the State's economy and is regularly the largest investing industry, with new capital investments exceeding $5 billion over the past ten years.

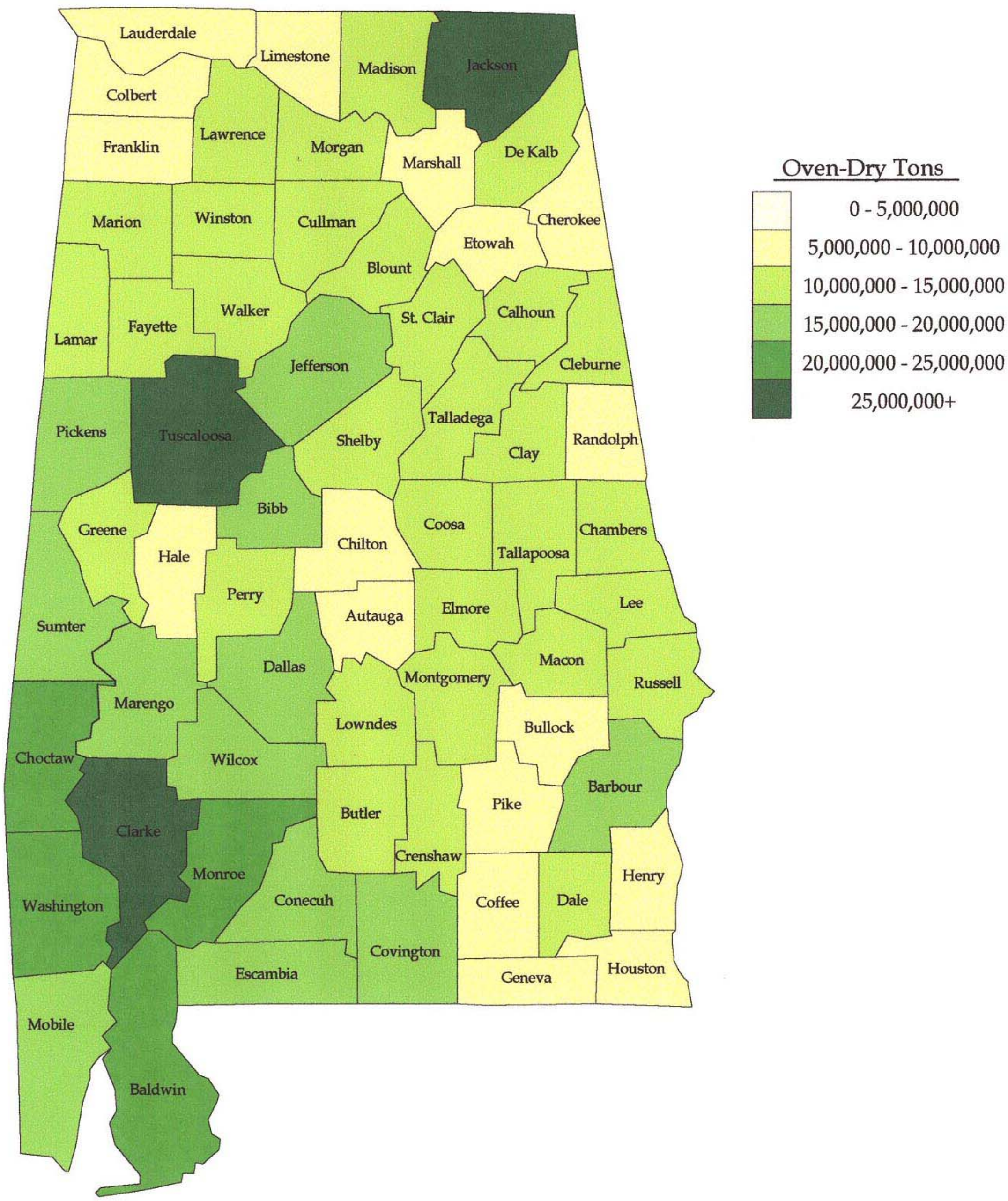
Alabama's productive forests and diverse manufacturing industry provide an array of sources for woody biomass that could potentially be utilized for the production of energy. These options would include standing woody biomass, forest residues, and manufacturing residues. Each of these categories includes a variety of wood species and fiber forms, each with their own special attributes and challenges. However, the primary determinant of which woody biomass fuels will ultimately be viable will be economics. Nevertheless, it is important to understand all of the potential options in order to assess the fuel potential under different economic and policy scenarios.

The widest and most encompassing view of potential woody biomass suitable for fuels would be the inventory of standing woody biomass. From a practical standpoint, of course, this volume of biomass would never be available to the fuel market. The standing forest biomass contains many higher-valued raw materials which are used for the production of a variety of wood and paper products. Consequently, this number should be used primarily as a point of reference, rather than a measure of actual fuel availability. However, understanding the maximum volume available is useful in establishing an upper boundary and in demonstrating the sizable base from which sustainable harvests of woody biomass can be conducted.

Standing Forest Biomass Inventory

The forest inventory data of the latest surveys were used to derive estimates of forest biomass availability for this report. These forest inventory data were obtained from the Forest Inventory and Analysis data bank collected by the Alabama Forestry Commission and maintained by the USDA Forest Service North Central Research Station. Standing forest biomass inventory is defined as the dry weight of all wood and bark above a one-foot stump in all live trees that are 1.0 inch or greater in diameter at breast height (4.5 feet above ground) and located on commercial forest land. It does not include stumps, foliage, seedlings, shrubs, vines, grasses, or other woody or non-woody plants. The standing forest biomass inventory consists of growing stock trees, cull trees, and small trees. Growing stock trees are those live trees of commercial species that are 5.0 inches or larger in diameter at breast height. Cull trees include: 1) all live trees of non-commercial species, and 2) those live trees of commercial species that do not contain a sawlog due to rot, roughness, poor form, splits, or cracks. Small trees are those live trees that are 1.0 to 5.0 inches in diameter at breast height.

FIGURE 4: STANDING BIOMASS INVENTORY IN ALABAMA



The total inventory of standing biomass in Alabama forests is estimated to be just under 900 million oven-dry tons. The heaviest concentrations of standing woody biomass can be found in the southwest and west-central portions of the state, where the land area of most counties is more than 80% forested. Portions of southeast and northwest Alabama have the lowest concentrations of standing woody biomass, as these regions have greater proportions of the land area devoted to agriculture. Nevertheless, every area of Alabama has substantial inventories of woody biomass, at least some portion of which could potentially be available for energy generation. Figure 4 displays the distribution of standing woody biomass in Alabama.

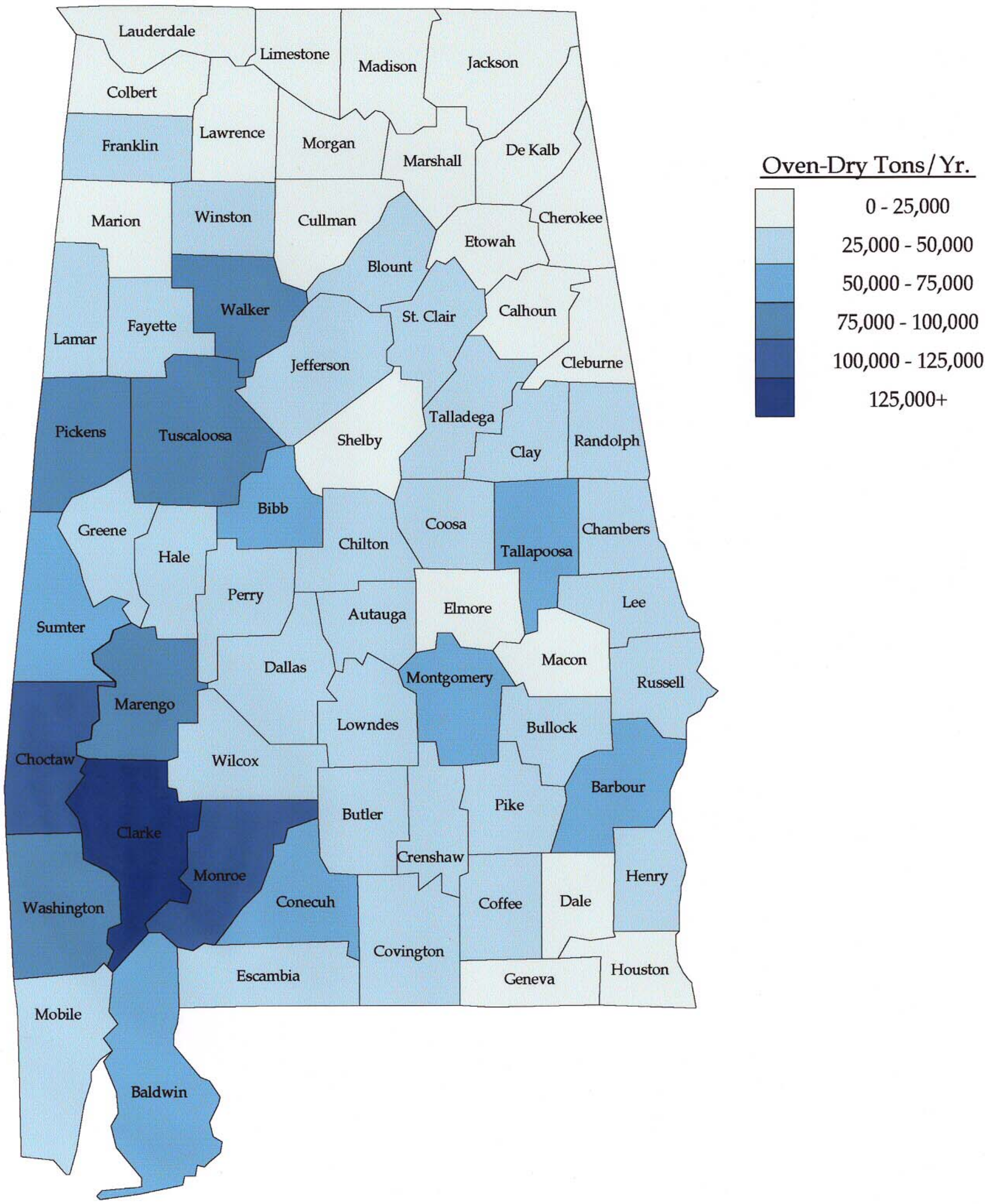
Forest Residue Availability

There are large volumes of woody biomass potentially available in the form of forest residues. Included in the broad category of forest residues are logging residues and cull trees. Logging residues typically consist of the crowns, limbs, and unused portion of the main stem of growing stock trees left in the forest after conventional harvesting operations. In Alabama, more than 1 billion cubic feet of merchantable timber is harvested each year. In the process of logging this vast amount of timber, an estimated 2.6 million oven-dry tons of logging residuals are generated. This woody biomass is typically not recovered and is most often either left in the forest, or is sometimes burned to clear the land prior to re-planting. Therefore, not only are logging residues not typically recovered, they also pose a forest management problem and cost in that they often complicate subsequent forest management activities. In certain areas, the presence of large volumes of logging residue on the forest floor can also contribute to potentially dangerous wildfire conditions.

Fortunately, logging residues can generally be easily reclaimed through the use of whole tree chipping operations. These operations produce "dirty chips", which include wood fiber, bark, and some foliage. A whole tree chipping operation can be conducted concurrently with the primary logging activities, or may follow in a separate cleanup operation. Either way, whole tree chipping is a well-understood practice with proven economics. This procedure not only claims valuable biomass fuels for energy, but may also provide forest management benefits as well. A cleaner logging site will mean less expensive site preparation and planting costs later on. In addition, reducing fuel loads on the forest floor can help mitigate potentially catastrophic losses from wildfire.

Logging residues are available throughout the state, but are most widely available in those heavily-forested regions where significant forest products manufacturing capacity exists. In these regions logging activity is most pronounced, thereby generating large volumes of residue. The most prominent producing region for logging residues would be the southwest portion of the state. The west central region also produces substantial logging residues, while the northern tier of counties has the least amount of logging activity. Figure 5 displays the distribution of logging residues in Alabama on a county basis. In total, approximately 2.6 million oven-dry tons of biomass could be recovered annually in Alabama in the form of logging residues.

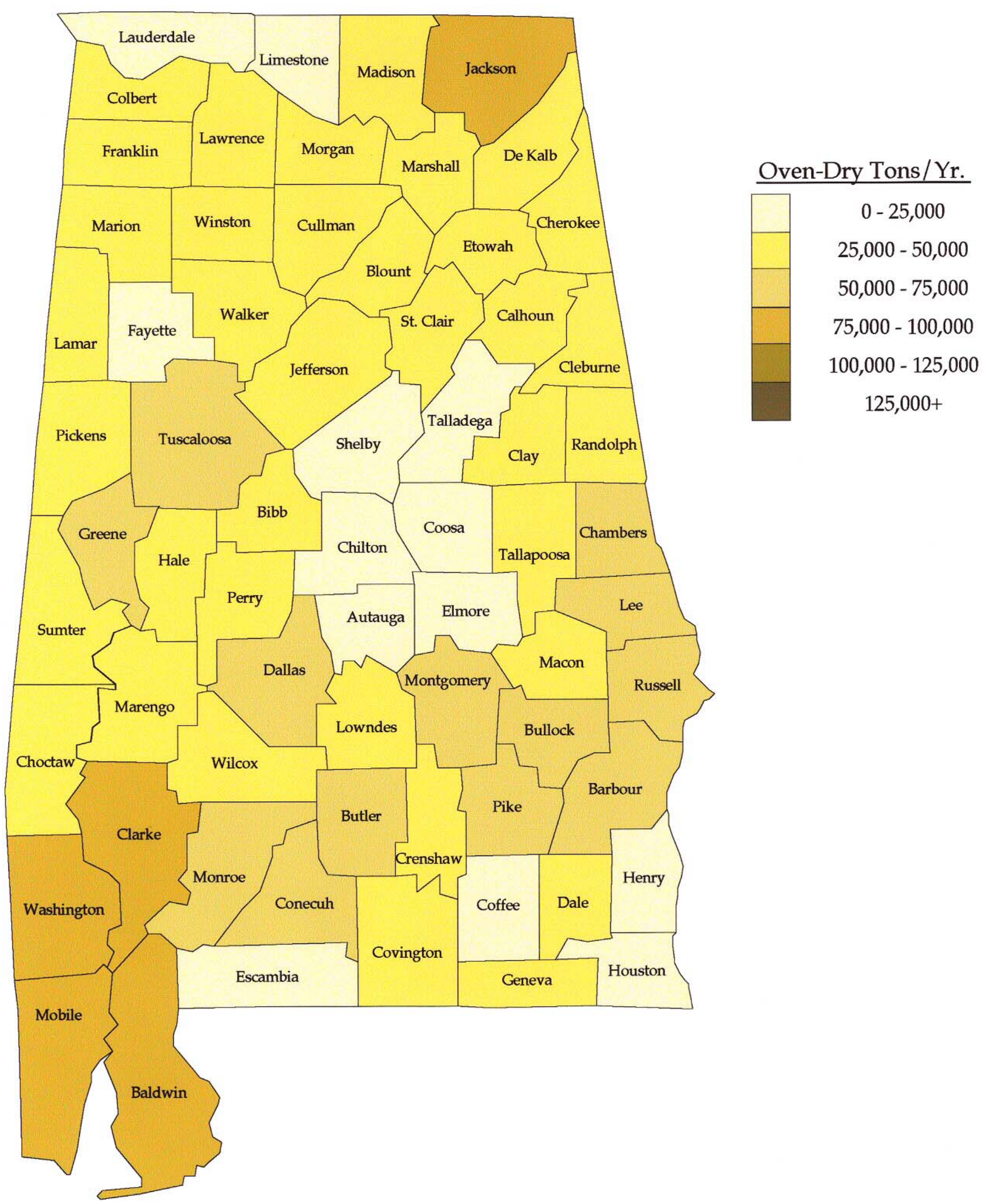
FIGURE 5: ANNUAL LOGGING RESIDUES IN ALABAMA



Another source of forest biomass potentially available for energy use is cull or rough trees. Cull trees account for slightly more than six percent of the total standing forest biomass inventory. These trees typically have no merchantable value beyond their potential for energy purposes. Therefore, this source of woody biomass represents a very viable fuel for energy purposes. As a practical matter, however, it is not possible to only harvest cull trees in most cases. Other trees would normally need to be harvested at the same time in order to keep costs manageable. Cull trees are usually harvested simultaneously with growing stock trees in a conventional logging operation. Thus, under normal economic conditions, the actual supply of cull trees for potential energy use is only the portion of the cull tree inventory that could be harvested simultaneously with growing stock trees.

It is estimated that there are approximately 2.7 million oven-dry tons of cull tree biomass that could be made readily available for energy use in Alabama. The estimated geographical distribution of this potential fuel is shown in Figure 6. The distribution shown is a func-

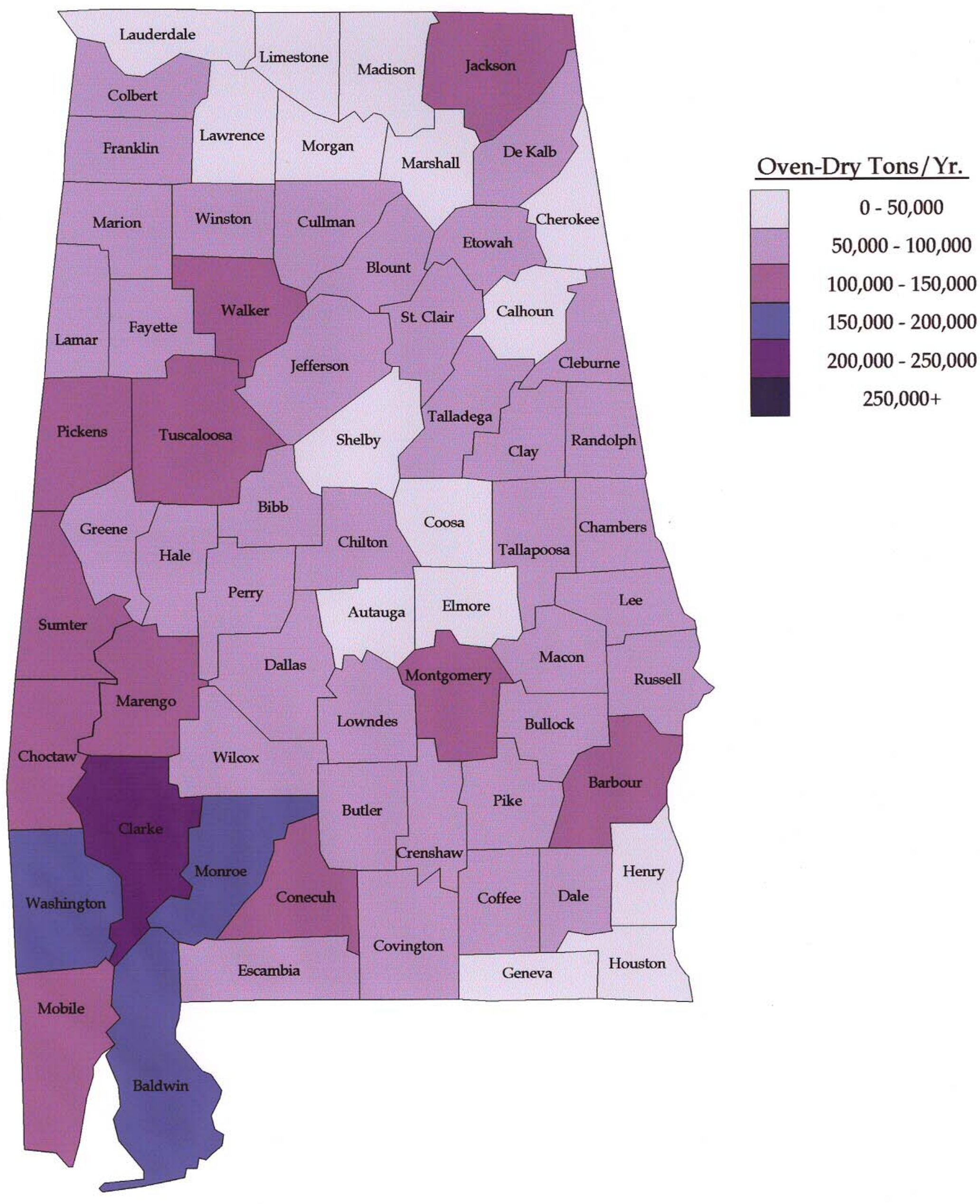
FIGURE 6: ANNUAL CULL TREE HARVEST POTENTIAL IN ALABAMA



tion of both the cull tree inventory and conventional logging activity.

Again, cull trees are probably best harvested along with higher quality trees during general logging operations. In order to efficiently recover the material, they may be processed through a whole tree chipper along with logging residues. All material would be blown into chip vans for transport to the energy conversion plant. In this way, all of the biomass that is generally unsuitable for use as raw material for forest products manufacturing can be recovered for productive use as fuel for energy production. Just as in the recovery of logging resi-

FIGURE 7: ANNUAL FOREST RESIDUE HARVEST POTENTIAL IN ALABAMA



dues, there are additional forest management benefits to be realized from the removal of cull trees from forest sites.

Figure 7 displays the geographic distribution of the combined forest residues that could be available in Alabama on an annual basis. Again, forest residues include both logging residues and cull trees harvested in conjunction with conventional logging operations. All of this material could be made available in the form of whole tree chips. The figure shows that the potential availability of forest residues is greatest in the southwest and west-central portions of the state. Availability is weakest in the southeast and northern areas of Alabama. The total estimated annual volume of forest residues in Alabama that could easily be recovered in the form of whole tree chips is estimated at 5.3 million oven-dry tons.

Primary Manufacturing Residue Availability

As previously mentioned, Alabama's forests support a very large and diverse forest products manufacturing sector. Major product categories include pulp, paper, lumber, wood panels, furniture, flooring, cabinets, and a variety of other value-added products. The forest industry is often categorized into primary manufacturing and secondary manufacturing sectors. The primary manufacturing sector includes those manufacturing industries that utilize round logs as raw material. Examples would include pulp and lumber manufacturing operations. The secondary manufacturing sector would include those segments of the industry that utilize a product output of the primary sector as raw material for value-added manufacturing. Examples would include furniture and flooring. Both the primary and secondary industry sectors produce wood waste materials as by-products of their manufacturing operations. Nearly all of these wood by-products have potential for use as fuel for energy production.

The primary manufacturing industry produces a variety of wood residuals from manufacturing operations that could be used for energy. These by-products include bark, sawdust, slabs, shavings, trim ends, chip fines, and others. The volumes of these residues produced in an individual mill depends on the nature and efficiency of the operation, along with its pro-

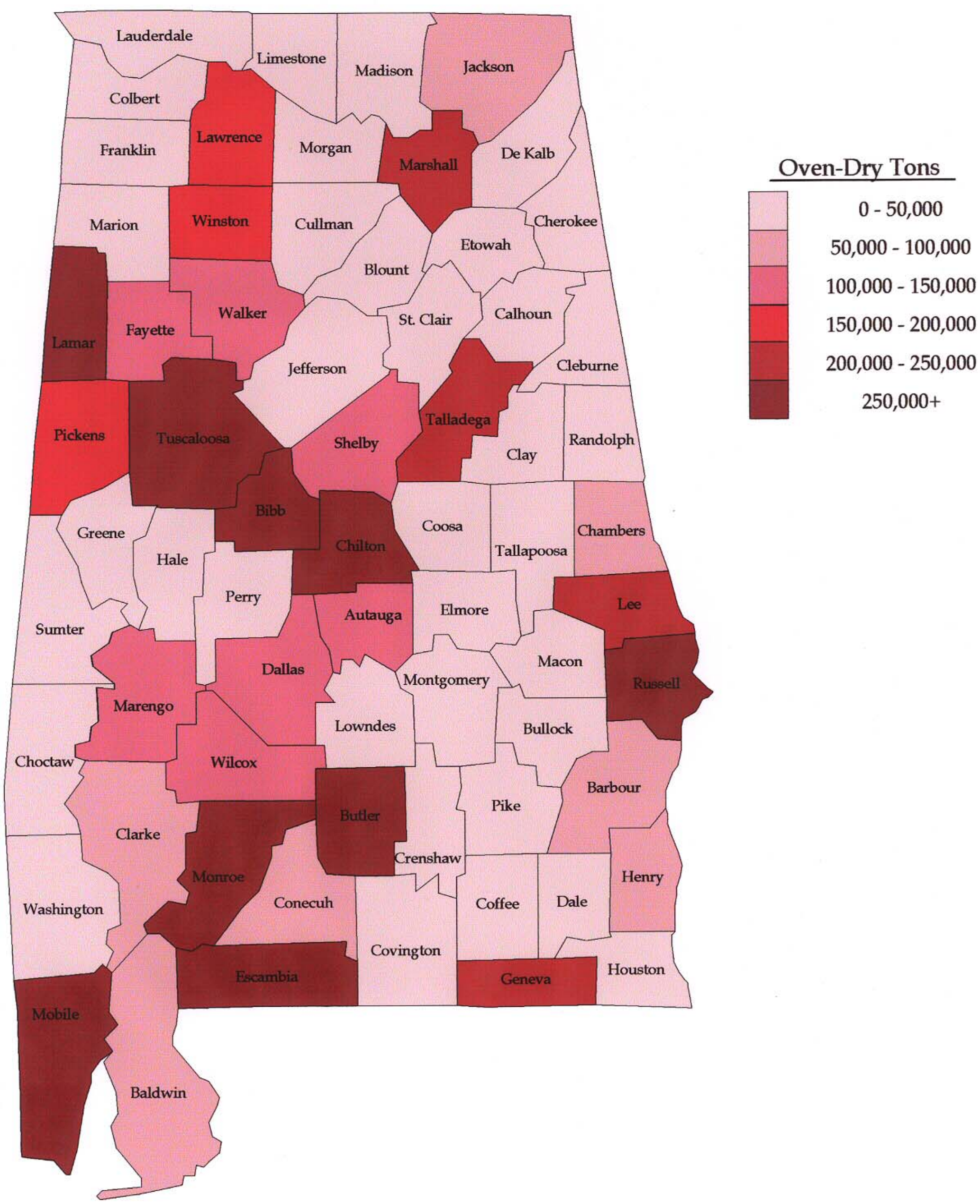
TABLE 2: MILL RESIDUE PRODUCTION FACTORS FOR WOOD PROCESSING OPERATIONS

Type of Operation	Residue Type	Typical Residue Production Factors	
		(% of log volume)	(lbs. per unit of product)
Sawmill	Bark	10%	915/mbf
	Chips	305	3250/mbf
	Sawdust	15%	1625/mbf
Chip Mill	Bark	10%	152/ton
Veneer Mill &	Bark	10%	335/msf3/8
Plywood Mill	Chips	30%	1305/msf3/8
OSB Mill	Bark	105	360/msf3/8
Pole Mill	Bark	10%	500/ccf
	Shavings	5%	300/ccf
Pulp Mill	Bark	10%	675/ton

duction volume. For example, a sawmill may produce mill residues of as much as 55% of the volume of input logs, while a pulp mill may produce only about 10%. Table 2 provides some general factors for estimating mill residue production from primary manufacturing operations.

Data regarding the volumes of primary mill wood residues in Alabama is available from the Alabama Forestry Commission, which periodically surveys the manufacturing industry of the state. Data collected during this industry survey includes both the volume, form and

FIGURE 8: PRIMARY MILL WOOD RESIDUE PRODUCTION IN ALABAMA



disposition of wood residues produced during manufacturing. Based on the available data, it is estimated that there are a total of nearly 6.8 million oven-dry tons of woody biomass produced annually in Alabama in the form of primary manufacturing residuals. Figure 8 displays the geographic distribution of these primary residiuals within the state.

Primary manufacturing residuals generally can be categorized as bark, coarse residues or fine residues. Coarse residues consist primarily of pulpable chips or waste wood capable of being converted to chips. Chips are generally "green", with a moisture content of approximately 50%. These chips are generally the most valuable of the primary manufacturing residues and are widely consumed by the pulp industry. Fine residuals generally consist of both sawdust and planer shavings. Like chips, most sawdust will have a moisture content of approximately 50%. Planer shavings, on the other hand, will normally have a moisture content of under 20%. Shavings are often utilized as raw material for particleboard and fiberboard manufacture. Most sawdust, however, is used for fuel, primarily in wood-fired boilers. A small amount of sawdust is sometimes used in both the pulp and panel industries, but there are limitations to the amounts that can be used due to the short fiber length of this material.

While primary manufacturing residuals are widely available in Alabama and throughout the South, it should be realized that nearly all of this material is currently being utilized in some manner. Data collected by the Alabama Forestry Commission shows that over 99% of all primary wood residuals are currently being used, primarily as fuel, fiber for pulp, fiber for panels, or mulch. Table 3 displays the disposition of primary residuals produced from Alabama manufacturing operations.

TABLE 3: DISPOSAL OF WOOD RESIDUE FROM PRIMARY MANUFACTURING OPERATIONS IN ALABAMA - 1999

(M Green Tons)

PRIMARY USE	BARK	CHIPPABLE	SAWDUST	SHAVINGS	PERCENT
Pulp Chips/Fiber Products	0	4,566	3	109	30%
Particleboard/MDF	0	114	218	538	6%
Charcoal/Chemical	0	0	0	0	0%
Sawn Products	0	108	0	0	1%
Industrial & Domestic Fuel	4,962	876	2,623	280	56%
Mulch	480	4	118	52	4%
Miscellaneous	102	14	251	64	3%
Not Used	6	3	17	2	<1%

Total Mill Residue - 15.5 Million Green Tons

Given that most primary manufacturing residuals are already being utilized, active markets exist for these materials in most areas. The availability of these materials as fuel for new energy-generating technologies is a matter of economics. In order to acquire these forms of woody biomass, new energy markets will have to be competitive with existing uses. As previously indicated, pulpable chips generally are the most valuable of the primary residues and are a significant source of raw material for the pulp industry. Shavings tend to be next on the primary residue value chain, as they are a prized raw material for particleboard and fiberboard production. Sawdust is less valuable than shavings, but generally more valuable than bark. Sawdust is primarily sold for fuel in wood-fired boilers and burners, but does have some limited application in fiber markets. Bark is ordinarily the least valuable of the primary residuals and is utilized primarily as either fuel or mulch. It should also be noted that many sawmill waste recovery systems collect bark and sawdust together, in which case the combined materials are sold to fuel markets as "hog fuel". The term is derived from the fact that the material is generally passed through a hammer hog to reduce it to a smaller and more consistent particle size.

While the markets for primary wood residuals can vary widely with both geography, business conditions, and local circumstances, Table 4 below provides some current ranges for primary wood residual prices in Alabama.

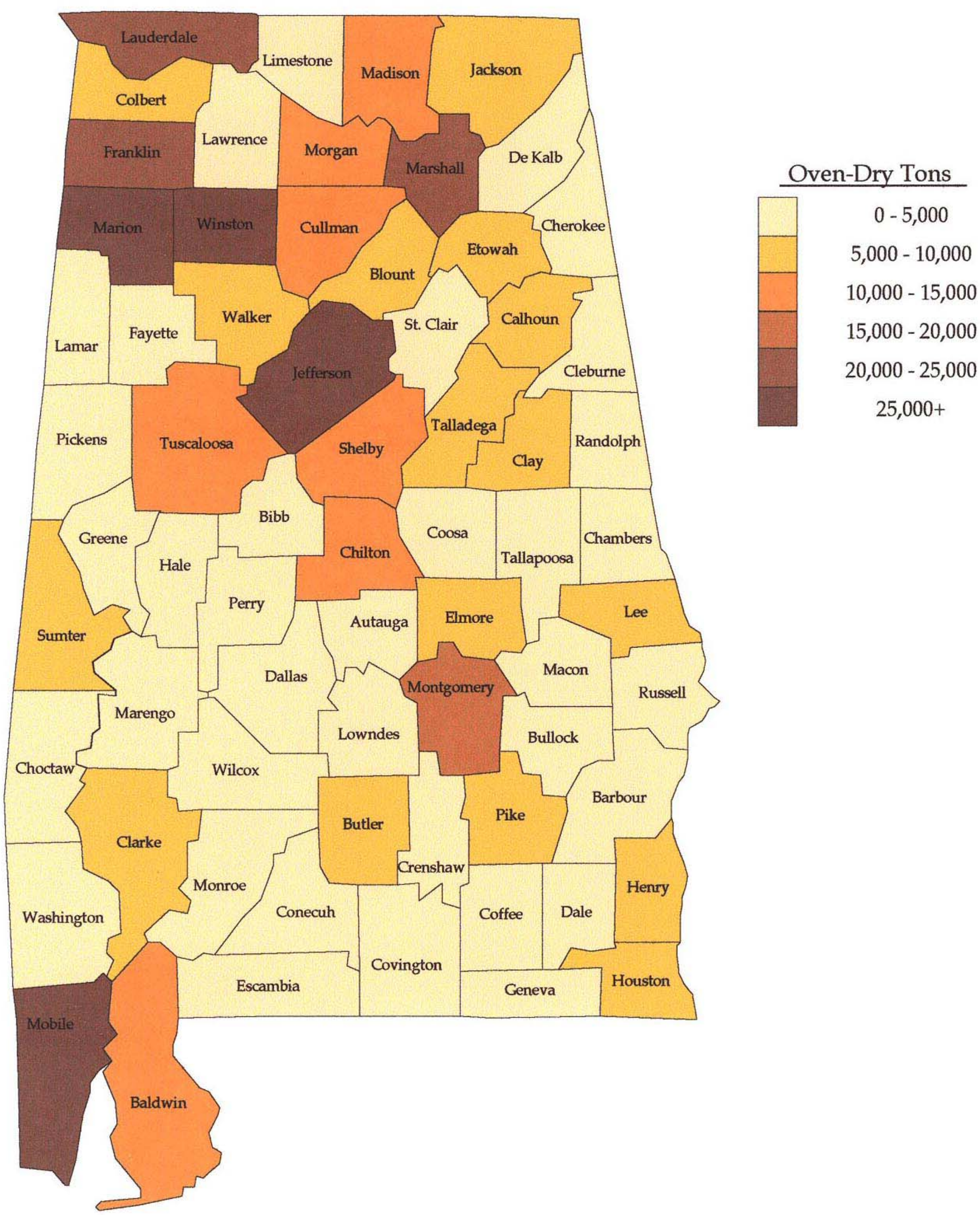
TABLE 4: CURRENT PRICE RANGES FOR PRIMARY WOOD RESIDUES IN ALABAMA (f.o.b. mill)

Residue Form	Price Range ($/oven-dry ton) Low	High
Bark	8.00	20.00
Sawdust	8.00	26.00
Shavings	17.50	35.00
Chips	30.00	50.00

Secondary Manufacturing Residue Availability

Alabama has a diverse secondary wood manufacturing sector that is comprised of over 800 manufacturing operations producing a wide variety of value-added products. These manufacturing operations also produce significant volumes of wood residuals as by-products of their manufacturing processes. Just as the secondary wood products and manufacturing processes are highly diverse, so are the nature of the by-products they produce. Secondary manufacturing wood residuals range from fine sander dust with low moisture content to large lumber cut-offs and trim ends with high moisture content. All manner of wood forms, species, and moisture contents may be included. While the volumes of secondary wood residuals produced in Alabama do not compare with those produced by the primary industry, they are nevertheless significant. Although there is very little hard data for residual volumes from this sector of the industry, it is estimated that secondary wood manufacturers in Alabama produce slightly more than one-half million oven-dry tons per year of residuals. Figure 9 displays the distribution of those materials throughout the state. Also interesting is the fact that the distribution of these wood residuals differs significantly from both forest residuals and primary manufacturing residuals in that they tend to be more concentrated in the northern counties of Alabama, particularly in the northwest region.

FIGURE 9: SECONDARY MILL WOOD RESIDUE PRODUCTION IN ALABAMA



Although the volumes of secondary wood residuals produced in Alabama are not huge when compared to other sources of woody biomass, they are an interesting potential source of fuel for energy production because of the favorable economics associated with some of this material. Markets for secondary wood waste are almost always limited to some sort of fuel use at best. Some of this material is landfilled, and thus has a negative value to the producer. Therefore, secondary wood waste has the potential to be an inexpensive fuel source for energy production. Since the material is highly variable in its physical charcteristics and is generally distributed among a large number of smaller producers, higher costs for collection and processing can be expected. Nevertheless, secondary wood waste can be considered as a potentially attractive fuel source for new energy production.

The preceeding data and discussion clearly indicates that Alabama has abundant sources of woody biomass materials that could provide a source of fuel in support of a biomass energy industry. Beyond those sources of woody biomass described above, there are several other potential sources of wood waste that deserve mention, but are not quantified herein. Urban wood waste may also provide a potential source of fuel. This material is often chipped and used for mulch, or is landfilled. Reliable data for Alabama is not available, but based on national estimates, it is probable that at least 100,000 oven-dry tons of this material is being produced annually within the state. Construction waste and demolition wood is another potential source of woody biomass for fuel, which is primarily landfilled in today's market. Although the material provides cleanup challenges for fuel use, there appears to be the potential of between 100,000 to 200,000 oven-dry tons of woody biomass annually within Alabama.

In addition to forest residues, manufacturing residues, urban waste and construction/demolition waste, there is growing interest in harvesting roundwood for energy conversion. The interest in developing an energy market for roundwood has arisen as a result of depressed fiber markets in recent years. Abundant pulpwood supplies, particularly for pine, have initiated considerable interest in utilizing low-end pulpwood, such as first thinnings, for energy purposes. Further speculation regarding the long-term potential for woody "energy crops" has also been considered. While these issues have merit and are deserving of further study and consideration, they are not explored within the scope of this report. The existing availability of lower-cost wood fuel options makes it unnecessary to consider comparatively costly roundwood for fuel at this time. It is believed that the extent of the fuel volumes required for the energy projects examined in this report can be readily satisfied with existing residue streams at lower cost. Therefore, we have focused our attention on those potential sources of woody biomass that can be procured most economically. Should a greatly expanded biomass energy industry be considered for Alabama's future, it would then be productive to examine the potential of roundwood production as a fuel source for such an industry.

Chapter Five

Alabama Sites for Synfuel Production

The biomass energy opportunity examined in this report is based on the conversion of woody biomass to syngas through gasification technology. The syngas would then be cleaned and blended with natural gas. This blend of synthetic and natural gas would then be used as the fuel for combined cycle power plants that would generate electricity. The resulting electricity would be sold and fed to the existing power grid.

Given the parameters of the opportunity as defined, potential sites for these synfuel projects are limited to the location of existing or proposed combined cycle power plants. The technology and locations of these plants within Alabama have been described in Chapter 2 of this report. Combined cycle power plants must be located where large diameter gas pipelines converge with electrical transmission lines. Opportunities for woody biomass synfuel projects are then confined to those sites, combined with areas that have substantial opportunity for the procurement of woody biomass fuels. The distribution of promising woody biomass fuels is explored in the previous chapter.

Based on the above criteria, three Alabama locations have been identified for further examination herein. It should be noted that these three locations were selected based on our determination of the existence of a favorable combination of requirements for such projects. This effort was not exhaustive in that we did not explore all possible sites within Alabama. Other locations within the state are likely to be viable for such a project, and may in fact even be more favorable than the three we have chosen here for deeper examination. Nevertheless, the locations identified herein meet the necessary criteria for this project and provide distinct geographical options in the northern, central, and southern regions of Alabama.

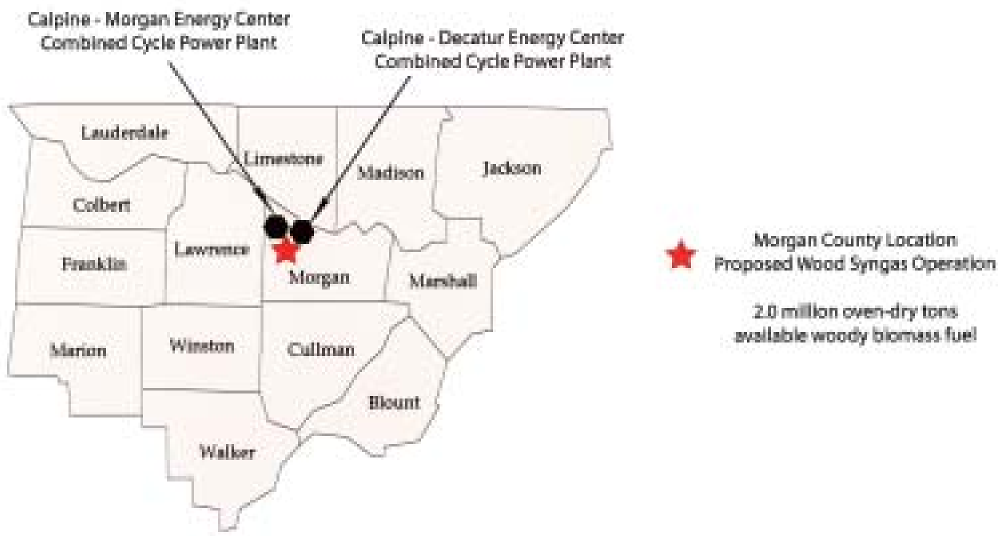
The three Alabama locations identified as viable for the wood-based syngas/combined cycle power technology are the Decatur area in Morgan County, the Autaugaville area in Autauga County, and the Mobile area in Mobile County. Each of these locations has at least one existing combined cycle power plant in operation and has ample supplies of available woody biomass that could be procured at reasonable prices.

Decatur - Morgan County

Currently under construction in the Decatur area of Morgan County are two combined cycle power plants which are wholly owned by Calpine, a public corporation and major independent North American power producer. The Morgan Energy Center will be operational in 2003 and will have a generating capacity of approximately 790 megawatts. The Decatur Energy Center is expected to come on line one year later with a planned generating capacity of 525 megawatts. Together, the two plants are expected to consume 125,000 scfm of natural gas when operating at full capacity.

A projected woody biomass procurement area around the Decatur location indicates a potential availability of 2.0 million oven-dry tons of forest residues and manufacturing residues. The procurement area encompasses portions of thirteen counties in northern Alabama. Figure 10 shows the proposed general location for a potential syngas production facility, the designated fuel procurement area, and the two combined cycle power plants currently under construction.

FIGURE 10: PROPOSED DECATUR AREA SYNGAS PRODUCTION FACILITY



The Decatur area location has a potentially attractive situation for procurement of woody biomass fuels due to the higher concentrations of secondary manufacturing wood waste in this region. Although this fuel source has certain potential operational problems due to its variability and the more difficult collection problems associated with it, the cost of this woody biomass could be comparatively attractive. Based on an annual requirement of 576,000 oven-dry tons of woody biomass fuel for our model facility, approximately 29% of the available forest and mill residues in this region would be required to fuel the operation. Because of a higher proportion of secondary wood waste in the mix, this location is projected to have the lowest delivered fuel cost at approximately $19.52 per oven-dry ton.

Our calculations for the woody biomass fuel mix and associated costs are based on procurement of the least cost material first, up to reasonable limitations. For purposes of this analysis, we have assumed that the operation could procure 70% of the secondary wood waste and 40% of the bark and sawdust produced in the region. Any additional fuel requirements are made up through the procurement of whole tree chips from forest residues. Since pulpable chips are more expensive than these alternative residuals, they were not included in our proposed fuel mix. Ample volumes of less expensive residuals appear to make it unnecessary to consider this and other higher cost fiber sources. Table 5 displays the volumes of woody biomass residuals available within the Decatur area facility's proposed procurement area, along with the proposed fuel mix and estimated cost figures.

TABLE 5: DECATUR AREA FACILITY - ESTIMATED WOODY BIOMASS SOURCING & COST

County	Secondary Residuals (oven-dry tons)	Primary Resid.-Bark (oven-dry tons)	Primary Resid.-Coarse (oven-dry tons)	Primary Resid.-Fine (oven-dry tons)	Whole-Tree Chips (oven-dry tons)	Total Residual Woody Biomass (oven-dry tons)
Blount	8,775	1,518	5,046	3,620	12,844	90,004
Colbert	5,757	3,857	10,580	9,203	56,368	84,765
Cullman	12,197	3,692	15,592	9,979	58,394	101,004
Franklin	11,135	5,078	13,053	3,858	56,683	101,037
Jackson	5,073	56,981	12,544	17,504	168,798	195,897
Lauderdale	20,071	1,379	2,003	3,454	35,568	62,612
Lawrence	1,598	157,294	0	0	46,799	205,691
Limestone	1,935	2,290	5,712	1,674	54,912	47,517
Madison	11,978	4,378	8,735	12,872	45,822	46,785
Marion	46,632	5,281	26,753	12,486	59,341	149,832
Marshall	20,573	25,139	130,935	79,450	38,100	303,497
Morgan	12,947	2,761	3,825	8,662	41,314	56,129
Walker	7,191	17,482	59,150	53,892	111,686	249,202
Winston	48,669	29,606	48,573	85,589	67,267	279,683
Total Available	228,732	318,933	350,989	284,336	837,844	2,026,866
Hypothetical Fuel Mix	158,706	126,773	0	113,735	176,787	576,000
Delivered Cost ($/o.d. ton)	8.33	15.60	42.17	22.36	28.12	19.52
Hypothetical Fuel Cost	1,322,316	2,408,681	0	2,543,104	4,971,245	11,245,057

Autaugaville - Autauga County

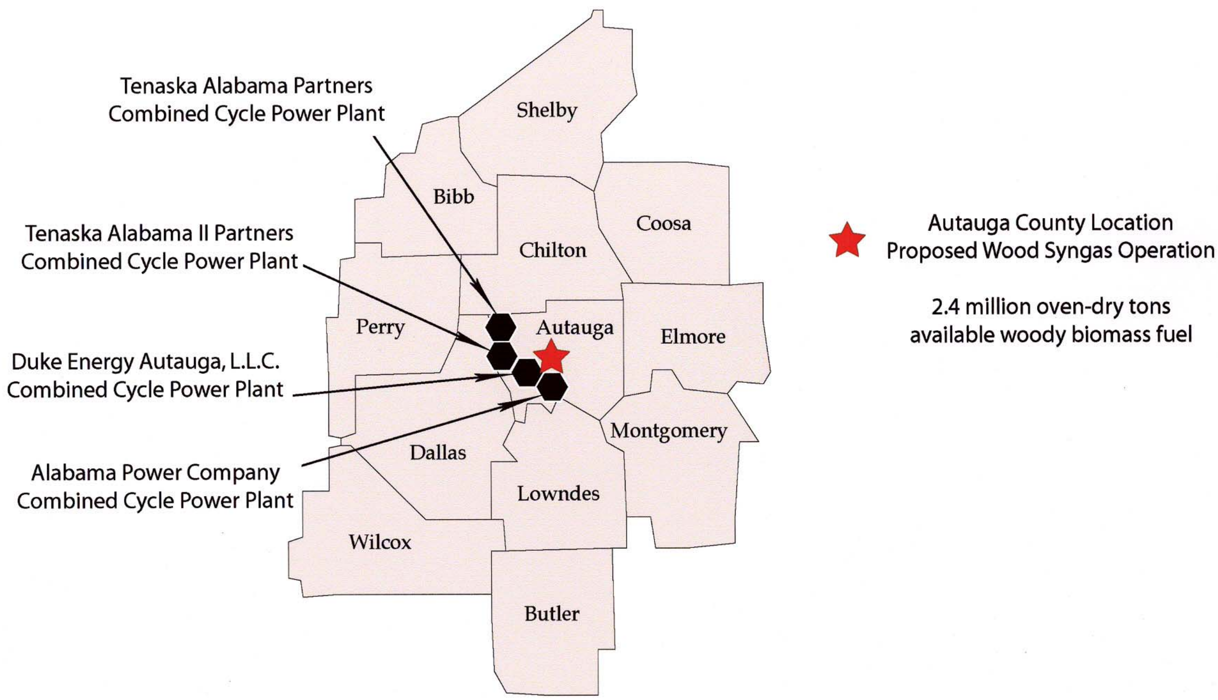
The Autaugaville area of Autauga County is home to three operational combined cycle power plants and one additional facility that has been permitted but has not yet been constructed. Two of the operational plants were built by Tenaska, Inc., a major diversified energy developer. Tenaska serves as the managing partner in a limited partnership which owns these facilities. The first of these Tenaska facilities has been operational for approximately one year and has a generating capacity of 845 megawatts. The second Tanaska facility has a capacity of 880 megawatts, and began operations in the second quarter of 2003. Both plants utilize natural gas and are expected to consume a combined total of 164,000 scfm of fuel at full capacity. In addition to the two Tenaska combined cycle facilities, a 1260 megawatt plant was built by Alabama Power Company, and is also a very recent start-up. Alabama Power Company is the largest electricity producer in the state. The Alabama Power facility at Autaugaville is expected to consume approximately 120,000 scfm of natural gas when operating at full capacity.

In addition to the three operational combined cycle facilities in Autauga County, a 630 megawatt facility has also been proposed by Duke Energy. Although this facility has received the necessary environmental permits for construction, the project is currently inactive. Duke

Energy is a major international electric power producer and diversified energy company. If the proposed project is ultimately constructed, it would represent an additional 60,000 scfm of natural gas consumption when at full capacity.

The concentration of both operating and proposed combined cycle power facilities in the Autaugaville area makes this location a natural site for consideration of a syngas production facility. An analysis of woody biomass availability within a twelve-county procurement area around the Autaugaville location indicates a potential availability of 2.4 million oven-dry tons of forest residues and wood manufacturing residues. Figure 11 shows the proposed general location for a potential syngas production facility, the designated fuel procurement area, and the four combined cycle power plant sites.

FIGURE 11: PROPOSED AUTAUGA COUNTY SYNGAS PRODUCTION FACILITY



The Autaugaville area location has significant availability of both primary manufacturing residuals and forest residuals. The availability of secondary manufacturing residuals is limited. Based on our model syngas facility's annual woody biomass fuel requirement of 576,000 oven-dry tons, approximately 24% of the available forest and mill residues in this region would be required to fuel this operation. The projected delivered fuel cost for this location under current market conditions is estimated at $22.07 per oven-dry ton. The cost of fuel at this location is projected to be slightly higher than at the Decatur site due to the lower proportion of low-cost secondary manufacturing residues in the fuel mix.

Again, our calculations for the woody biomass fuel mix and associated costs are based on procurement of the least cost material first, up to reasonable limitations. For purposes of this analysis, we have assumed that the operation could procure 70% of the secondary wood waste and 40% of the bark and sawdust produced in the region. Any additional fuel requirements are made up through the procurement of whole tree chips from forest residues. Since pulpable chips are more expensive than these alternative residuals, they were not included in our proposed fuel mix. Ample volumes of less expensive residuals appear to make it unnecessary to consider pulp chips and other higher cost fiber sources. Table 6 displays the volumes of woody biomass residuals available within the Autaugaville area facility's proposed procurement area, along with the proposed fuel mix and estimated cost figures.

TABLE 6: AUTAUGAVILLE AREA FACILITY - ESTIMATED WOODY BIOMASS SOURCING & COST

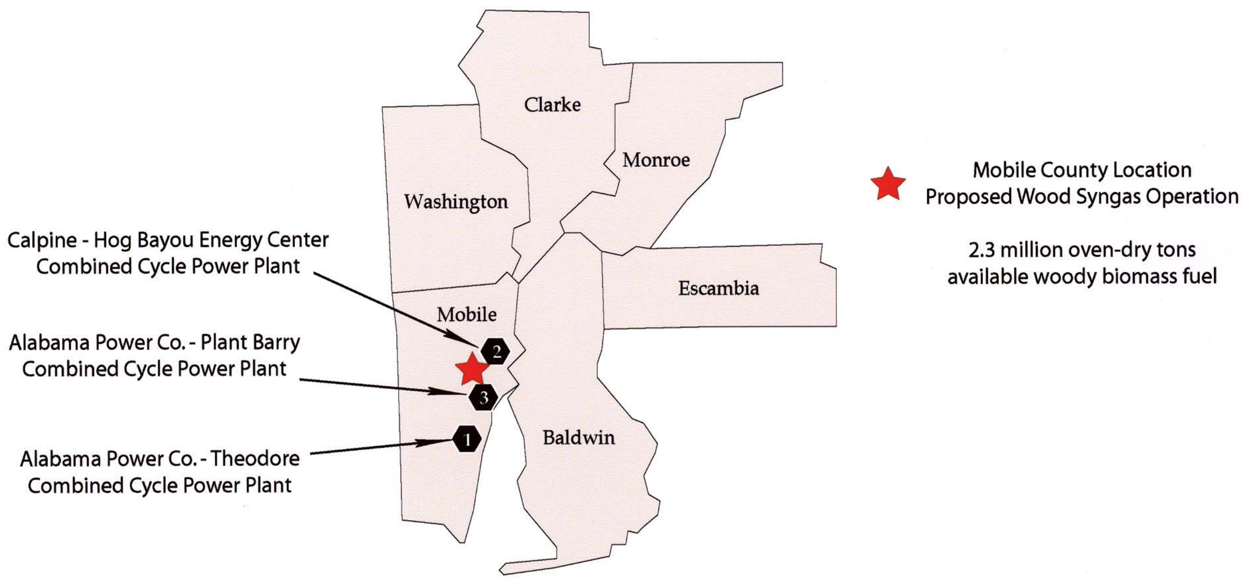
County	Secondary Residuals (oven-dry tons)	Primary Resid.-Bark (oven-dry tons)	Primary Resid.-Coarse (oven-dry tons)	Primary Resid.-Fine (oven-dry tons)	Whole-Tree Chips (oven-dry tons)	Total Residual Woody Biomass (oven-dry tons)
Autauga	4,066	84,138	27,561	13,099	43,963	172,826
Bibb	3,847	128,430	109,975	35,350	92,842	370,444
Butler	5,005	38,984	127,610	121,079	99,844	392,522
Chilton	11,603	43,918	146,293	139,945	57,641	399,399
Coosa	3,281	3,769	7,122	8,328	41,921	64,421
Dallas	4,691	20,148	31,215	61,688	93,335	211,077
Elmore	6,574	713	2,465	1,673	35,665	47,089
Lowndes	627	6,853	23,612	13,389	83,597	128,078
Montgomery	18,478	7,841	26,114	7,987	114,509	174,929
Perry	0	2,446	6,553	1,341	74,057	84,397
Shelby	10,045	16,958	51,490	32,227	45,042	155,761
Wilcox	2,837	18,486	62,636	58,935	85,325	228,218
Total Available	71,055	372,681	622,644	495,043	867,739	2,429,161
Hypothetical Fuel Mix	49,738	149,072	0	198,017	179,172	576,000
Delivered Cost ($/o.d. ton)	8.33	19.00	42.12	22.36	28.12	22.07
Hypothetical Fuel Cost	414,321	2,832,376	0	4,427,664	5,038,318	12,712,679

Mobile - Mobile County

The Mobile area is home to three operational combined cycle power plants. Two of these operations are owned and operated by Alabama Power Company. The two power plants have a combined generating capacity of 1,210 megawatts and will consume approximately 115,000 scfm of natural gas when operating at full capacity. The third facility is owned and operated by Calpine and has a generating capacity of 245 megawatts. This operation would consume slightly more than 23,000 scfm when operating at full capacity.

The Mobile area is located in proximity to one of the most heavily forested areas of the South and is also home to a large number of forest products manufacturing operations. As such, the location is well situated with respect to the procurement of woody biomass fuels. A potential procurement area encompassing a six-county area appears to contain at least 2.3

FIGURE 12: PROPOSED MOBILE COUNTY SYNGAS PRODUCTION FACILITY



million oven-dry tons of forest residues and manufacturing residues that could be available for the production of syngas. Figure 12 displays the proposed general location of a potential syngas production facility, the defined fuel procurement area, and the three combined cycle power plants currently operating in the area.

The Mobile area location is a potentially attractive location for the production of syngas due to the volume of forest residues and manufacturing residues produced in this heavily-forested area of the state. The closure of two large pulp mills in the area in recent years has removed a major consumer of woody biomass from the market. New markets for this material are needed and would likely be welcomed by existing producers. Based on the annual fuel requirement of 576,000 oven-dry tons of woody biomass for our model facility, slightly less than 25% of the forest and mill residues in this region would be required to furnish the proposed syngas operation. An average fuel cost of $21.53 per oven-dry ton is projected under current market conditions.

As previously described, our calculations for the woody biomass fuel mix and associated costs are based on procurement of the least cost material first, up to reasonable limitations. For purposes of this analysis, we have assumed that the operation could procure 70% of the secondary wood waste and 40% of the bark and sawdust produced in the region. Any additional fuel requirements are made up through the procurement of whole tree chips from forest residues. Since pulpable chips are more expensive than these alternative residuals, they were not included in our proposed fuel mix. Ample volumes of less expensive residuals appear to make it unnecessary to consider this and other higher cost fiber sources. Table 7 displays the volumes of woody biomass residuals available within the Mobile area facility's proposed procurement area, along with the proposed fuel mix and estimated cost figures.

TABLE 7: MOBILE AREA FACILITY - ESTIMATED WOODY BIOMASS SOURCING & COST

County	Secondary Residuals (oven-dry tons)	Primary Resid.-Bark (oven-dry tons)	Primary Resid.-Coarse (oven-dry tons)	Primary Resid.-Fine (oven-dry tons)	Whole-Tree Chips (oven-dry tons)	Total Residual Woody Biomass (oven-dry tons)
Baldwin	10,973	26,180	18,360	11,675	165,778	232,965
Clarke	7,527	9,572	21,490	29,039	207,960	275,587
Escambia	3,187	188,002	110,989	61,132	66,921	430,230
Mobile	29,724	173,072	161,694	152,291	113,284	630,063
Monroe	3,154	193,566	98,536	111,565	183,590	590,410
Washington	713	4,158	10,125	8,640	156,873	180,509
Total Available	55,279	594,547	421,193	374,342	894,404	2,339,765
Hypothetical Fuel Mix	38,695	237,819	0	149,737	149,749	576,000
Delivered Cost ($/o.d. ton)	8.33	19.00	42.12	22.36	28.12	21.53
Hypothetical Fuel Cost	322,332	4,518,557	0	3,348,117	4,210,942	12,399,948

The analysis suggests that the three locations discussed herein contain the necessary elements to support a syngas production facility that would supplement the natural gas supply for existing combined cycle power plants. In each case there are multiple power generating facilities present, any one of which could provide a potential market and/or operating partner for such a facility. In addition, each location examined is situated within a promising procurement area for woody biomass fuels. Each location appears to have access to a minimum of 2 million oven-dry tons of forest residues and manufacturing residues. Under current market conditions, the average cost of these fuels would range from approximately $19.50 to $22.00 per oven-dry ton. There are no known barriers to entry for such a facility at any of the three locations identified.

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Chapter Six

Model Project Economics

The syngas production project as described in this report is conceptual in that no commercial operation of a similar scale currently exists. A commercial woody biomass gasification unit currently operates in New England in conjunction with a gas combustion turbine to generate electricity at the McNeil Generating Station. This unit, which is owned and operated by FERCO Inc., is located in Burlington, Vermont. The process is conceptually similar to that envisioned in this report, but differs importantly in terms of the scale of the operation. The FERCO unit utilizes a maximum of approximately 400 oven-dry tons per day of woody biomass residues in its gasification system. The project model examined in this report would be approximately four times larger. On first examination this may seem to be a significant stretch of the current status of large-scale biomass gasification technology. However, our base model utilizes a series of four identical gasifiers per operation, each of which would be similar in size to the FERCO unit. Therefore, the scale of the gasifier operation itself is not out of line with proven technology. The scale of peripheral systems, such as fuel processing and gas cleanup would be significantly larger; however, there is nothing technologically complex with regard to scaling up these components of the operation. In short, the model described below is believed to be a feasible application of current technology. The model was developed by Tourtellotte & Associates LLC (TALLC), based on computer models of their proprietary large-scale gasification system. While other workable large-scale gasification systems may be available, the TALLC model was utilized for purposes of this report. It will be incumbent upon any prospective investor considering investment in large-scale biomass gasification to fully evaluate the relative technological merits of alternative production systems.

Syngas Model Description

Fuel: Woody biomass would be purchased from an approximate 60-mile radius and would include both pine and hardwood residues. Primary manufacturing residues would comprise the largest component of the fuel mix and would include both bark and green sawdust. Also included in the fuel mix would be whole tree chips derived from both logging residues and cull trees. Finally, secondary manufacturing residues would be included, but would likely be the smallest component of the fuel mix. The proportions of these woody biomass fuel types would vary by location, based on specific availability and economics. Approximate volumes of each component at each of the three sites considered are shown in Tables 5, 6 and 7 in the previous chapter.

Based on our production model, a total fuel volume of 576,000 oven-dry tons per year would be required.

Fuel Handling/Processing: Woody biomass fuel would be delivered by truck in covered chip/fuel vans with an average capacity of approximately 13 oven-dry tons per van. Trucking of wood residues would be accomplished primarily by independent contactors. Based on the system capacity, an average of 125 truck loads of fuel would be delivered daily. Chip/fuel vans would be unloaded by means of chip dumps. Manufacturing residuals requiring resizing would be diverted to a hammer hog where they would be reduced to a uniform particle size. It is expected that much of the primary residues received at the operation would already have passed through a hammer hog at the plant of origin. Whole tree chips would not require hogging. Much of the secondary wood residuals would likely require processing in a hammer hog to reduce the material to a uniform size.

After unloading and initial processing, dry fuel (below 15% M.C.) would be diverted to storage bins or silos. Since the moisture content of the fuel deliveries will vary from a low of approximately 7% to a maximum of around 50%, it will be preferable to separate the materials based on whether or not drying is required. High-moisture material would be placed on a storage pad where it could be reclaimed and conveyed to chip dryers, as needed. A moisture content of approximately 10% would be targeted as ideal for maximum syngas production.

Dried fuel would be conveyed to the dry fuel bins or silos. Each of the four gasifier systems would have a dedicated chip dryer and fuel storage bin/silo. These bins/silos would provide dry storage, as well as a fuel surge area ahead of the gasifiers. The redundancy designed into the fuel system will help maintain a high on-line system availability.

Gasifiers: The proposed model operation would include four separate gasifications systems, each of which would require eighteen oven-dry tons per hour of woody biomass fuel. Based on an on-line availability rate of 91%, approximately 8,000 hours of actual operation per gasifier is planned. This equates to 144,000 oven-dry tons per year of fuel consumption for each gasifier. Thus, the four gasifiers would utilize a combined 576,000 oven-dry tons per year.

The TALLC gasification system would operate in the range of 1,500 - 1,600 F. The process transfers all the energy needed for the gasification process indirectly. No air or steam is injected into the process. Based on previous research, a recovery of approximately 28,300 scf of syngas per oven-dry ton of woody biomass is expected. Based on the system fuel consumption of 72 oven-dry tons per hour, the syngas production from the facility is calculated to be 2.04 million scf per hour. At a lower heating value of 459 Btu per scf of syngas, the system would generate 935.4 million Btu/hour. This level of syngas production would be sufficient to generate approximately 155 MW of electricity. Therefore, the gasification system proposed would be capable of producing anywhere from 12% to 60% of the energy required at the combined cycle facilities considered at the three Alabama locations examined in the previous chapter, depending upon which specific facility is chosen.

Gas Cleanup: Gas cleanup would be accomplished via a 3-stage system that would remove all particulates in excess of 3 microns. Residual ash and trace metals remaining would be less than 0.1 ppm. A catalyst system similar to those utilized in both conventional steam and gas turbine power plants would be employed. Specifically, a nitrogen oxide selective catalytic removal system would be used, with proven systems being available from several suppliers. Because gasification in the model system is accomplished at relatively low temperatures, the vaporization of undesirable compounds is minimized. Consequently, gas cleanup is facilitated and the operating life of the catalyst used is extended. Based on published process specifications for fuel gases for combustion in heavy-duty gas turbines, the model syngas cleanup system is expected to provide a gas fuel clean enough to meet all turbine manufacturer's specifications.

Following cleanup, the syngas would be diverted to one of four gas compressors that would bring the gas to the required pressure for the gas turbines, approximately 500-600 psi. The pressurized gas would then be blended with natural gas in the pre-determined proportions necessary to fuel the turbines and associated generator.

Site & Other: In addition to the above described primary components, the facility would include an office building and maintenance facilities. Ideally, the facility would be located adjacent to or in very close proximity to the combined cycle power plant. Site requirements would be approximately 20 acres of usable land with good road access. Due to the high volume of truck traffic for fuel deliveries, road access is an important consideration. Rail access is not mandatory, but would be a positive consideration for possible fuel deliveries. Capital estimates in this report, however, do not include rail spurs or rail car unloading systems.

Manning: The proposed operation, as modeled, would operate on an around-the-clock basis. The operation would require a total employment of 92 persons, which does not include any forest harvesting operations. It is assumed that all harvesting and trucking functions would be performed by independent contractors, which are readily available in the marketplace.

Most employees would be hired from the local area. Programs would be developed and utilized to train employees in the safe and efficient operation of the equipment. Other than several proficient millwrights and electricians for the maintenance department, no specialized skills would be required. Facility management would probably come from outside the area initially, but local management could likely be developed in a reasonable time frame.

TABLE 8: MANNING TABLE FOR ALABAMA SYNGAS PLANT

Department	People/Shift	No. of Shifts	Total
Woodyard	8	4	32
Gas production	8	4	32
Maintenance	3	4	12
Security/plant services	2	4	8
Administration	8	1	8
Total			92

Syngas Model Economics

The proposed syngas production project would require a total estimated capital investment of $96.0 million. The project economics are highly dependent upon three primary factors. These would include 1) the price of natural gas, 2) the delivered price of woody biomass fuel, and 3) public policy which may provide tax incentives and/or grants for producing energy from renewable woody biomass. All of these elements of the investment outlook have been highly volatile recently, creating considerable uncertainty that is a disincentive for attracting investment capital into such a venture.

Natural gas prices have been highly volatile in recent years and highly variable by geographic region. Prices are influenced by weather, politics, substitution effects, production levels, and distribution constraints. During the last two years, natural gas prices to electric utilities in Alabama have ranged wildly from a low of $2.44/mcf to a high of $9.75/mcf. Obviously, the investment returns for the proposed project vacillate even more widely as a result of the swings in revenue that are a consequence of such extreme price movements. At a natural gas price of $2.44/mcf, the project does not produce a positive return under most plausible scenarios. However, a natural gas price of $9.75/mcf would result in a highly profitable operation with projected investment returns high enough to easily attract the necessary investment capital. For the year 2002, natural gas prices to electric utilities averaged $3.74/mcf or the equivalent of approximately $4.11 per mmBtu. We have used this price in our base case investment return model. A summary of the investment returns are shown in Table 9, with more detail of the analysis available in Appendix B.

Woody biomass prices are also highly important to the outcome of the economic analysis. While woody biomass prices have generally not shown the volatility of natural gas prices, they do move up and down with industry conditions. More recently, the price of woody biomass fuels have been influenced by the prices for fossil fuels, and in particular for natural gas. Also, growing markets in alternative uses for woody biomass residues have also put upward pressure on prices. Examples would be bark for mulch and landscaping materials, shavings and sawdust for animal bedding, and bark and wood residues for charcoal production. While we have calculated the average woody biomass price in the areas of interest as ranging from $19.52 to $22.07 per oven-dry ton in recent markets, there has been recent upward price pressure on these residues that could push prices higher in the future. Again, the project economics will be highly dependent on the price of woody biomass fuels. Our "base case" analysis utilizes a price of $20.00 per oven-dry ton, but we have also examined the impact on investment returns of woody biomass fuel at $30.00, $40.00, and $50.00 per oven-dry ton. Again, a summary of the investment analysis can be found in Table 9, with detail available in Appendix B.

Tax incentives & grants have been made available to various segments of the energy industry as a result of public policy to promote certain technologies deemed to be in the interests of our society. These have been primarily promoted as a means of facilitating greater energy independence, reducing the pollutant levels associated with fossil fuels, or both. The production of ethanol from grain is a prime example. The ethanol industry could not exist in its present form without the incentives provided by government policy to promote this renewable, but expensive, energy source.

Various tax incentives and grants have also been proposed for the production of energy from woody biomass. These incentives fall primarily into two areas, 1) tax credits and grants for the use of renewable biomass fuels for the production of electrical energy, and 2) tax credits for the reduction of greenhouse gases as compared to fossil fuel power plants. The details and merits of the many proposals in this regard will not be explored in this document. However, it is important to recognize that the investment returns of the proposed project can be hugely affected by these incentives. As an example, our base case analysis shows that the projected return on investment is not large enough to attract the necessary capital if no tax incentives or grants are available. With all proposed incentives in place, the projected investment returns become very promising and would likely result in attracting sufficient risk capital to make the project a reality. Table 9 below displays the effect of proposed incentive and grants on the investment returns of our project model. Again, more detail is available in Appendix B.

TABLE 9: PRO FORMA INVESTMENT RETURNS FOR MODEL SYNGAS PROJECT

Return on Investment (%)

Wood Cost ($/o.d. ton)	No Tax Credits	Proposed Biomass Tax Credit	Proposed Biomass Tax Credit + Greenhouse Gas Credits
$20	6.0	37.1	71.0
$30	0.0	31.1	65.0
$40	(6.1)	25.0	59.0
$50	(12.1)	18.9	53.0

The above table shows that, while investment returns are slightly positive with current natural gas and woody biomass prices, they are not sufficient to attract the required investment capital. Given the recent history of price volatility for key variables, and the fact that the proposed operation would be the first of its kind on a scale of this magnitude, projected investment returns will have to be very attractive to bring in the necessary capital for this project. On the other hand, the application of proposed tax incentives for these technologies could easily raise the project returns above the likely threshold to attract this capital. A combination of higher fossil fuel prices and tax incentives for biomass energy projects could have a very positive effect on the development of a wood-based biomass energy industry.

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Chapter Seven

Conclusions

There are many good reasons to consider renewable biomass energy projects. For public policy makers, renewable biomass energy has the potential to decrease the nation's dependence on imported fossil fuels, to improve environmental quality by reducing greenhouse gases, and to create economic development opportunities both by creating new markets for domestic agriculture and forestry products and by facilitating investment in new energy production operations. For investors, the potential of renewable biomass energy is to be on the front end of what could potentially be a significant growth industry. History clearly shows that the most attractive investment returns normally derive from early investments in new growth industries.

The evolution of the electric power generating industry and the establishment of a large portfolio of combined cycle power assets throughout the Southeast has resulted in increased demand for natural gas. The development of large-scale gasification technologies for biomass suggests that an opportunity may exist to replace natural gas with syngas produced from woody biomass. Our analysis suggests that such an operation would be technically feasible in that commercial systems are currently available for the processing of woody biomas fuels, the gasification process, and the required syngas cleanup that could be adapted to the scale of the project envisioned herein. A model project has been developed and evaluated both technically and economically.

Our examination of the potential for woody biomass-based syngas production for use in combined cycle power plants in Alabama reveals that there are aspects of these energy projects that are both promising and challenging. Clearly, the data shows that there are abundant woody biomass fuels available within the state to fuel very large-scale operations that could supply significant volumes of syngas to either existing or planned combined cycle power plants that are currently fueled by natural gas. The analysis shows that approximately 2 million oven-dry tons of woody biomass fuels are potentially available within a reasonable procurement area of three selected locations in Alabama that are already home to combined cycle power operations. The three sites examined, Decatur, Autaugaville and Mobile, all appear to be potentially viable sites for such a facility. Other sites in Alabama may also be attractive, but were not examined in this study.

Our analysis also suggests that woody biomass could be delivered to any of our three hypothetical syngas facility sites for less than $25 per oven-dry ton, based on recent market conditions. Markets for wood residuals can be volatile, however, and the recent trend has been upward with growing demand for boiler fuel, landscaping mulch, and other competing uses. Likewise, the price of natural gas has been extremely volatile in recent years, thereby introducing another element of uncertainty into the analysis. Based on the 2002 annual average price of natural gas to utility users in Alabama, our analysis suggests that the investment returns for the project in question would not be attractive enough to warrant the $96 million in required capital investment. However, natural gas has risen to prices for short periods that would provide fantastic returns on investment, while also falling to levels for short periods that would be financially disastrous to the project economics. Clearly, the direction and stability of natural gas prices is a crucial issue for the viability of these proposed syngas projects.

Our analysis suggests that it is currently unlikely that investments will be made in the proposed technology without some form of public incentives. It has been suggested above that there are very real reasons that public policy makers should at least examine the merits of such incentives. Energy independence, national security, environmental quality, and economic growth are all highly important public benefits that might be furthered through the development of a renewable biomass energy industry, such as that examined in this report. With the right mix of incentives in place, large-scale operations for the production of wood-based syngas could become a reality. By teaming with combined cycle power producers, these syngas operations could play an important role in generating electricity for Alabama's future economic growth.

APPENDICES

Appendix A
Alabama Woody Biomass Resource Data

Alabama Woody Biomass by County

County	Softwood Woody Biomass (oven-dry tons)	Hardwood Woody Biomass (oven-dry tons)	Total Woody Biomass (oven-dry tons)
Autauga	3,238,987	5,180,705	8,419,692
Baldwin	10,189,527	11,869,413	22,058,940
Barbour	7,193,750	9,148,096	16,341,846
Bibb	7,304,071	9,302,506	16,606,578
Blount	3,025,789	7,367,327	10,393,116
Bullock	3,913,626	5,504,088	9,417,714
Butler	7,094,436	6,268,817	13,363,253
Calhoun	2,958,528	7,525,875	10,484,402
Chambers	6,003,223	5,785,738	11,788,961
Cherokee	2,548,337	6,276,363	8,824,700
Chilton	2,190,987	6,765,583	8,956,570
Choctaw	11,888,841	11,620,443	23,509,284
Clarke	14,998,863	17,790,357	32,789,220
Clay	4,056,950	7,604,582	11,661,532
Cleburne	5,775,141	8,474,544	14,249,685
Coffee	3,635,553	4,860,615	8,496,168
Colbert	1,379,382	8,462,094	9,841,476
Conecuh	7,078,187	8,829,388	15,907,575
Coosa	5,579,580	7,471,896	13,051,475
Covington	8,546,374	7,106,681	15,653,055
Crenshaw	4,533,839	8,202,275	12,736,114
Cullman	2,379,720	8,050,456	10,430,176
Dale	3,881,906	7,677,931	11,559,837
Dallas	5,254,393	11,766,546	17,020,939
DeKalb	3,250,217	7,655,178	10,905,396

Elmore	2,833,677	7,194,696	10,028,372
Escambia	8,926,780	6,595,658	15,522,438
Etowah	1,462,864	8,410,675	9,873,539
Fayette	3,737,516	7,822,685	11,560,200
Franklin	1,789,918	8,102,850	9,892,768
Geneva	2,644,952	4,860,803	7,505,755
Greene	3,423,031	11,234,357	14,657,388
Hale	3,072,356	6,887,873	9,960,229
Henry	2,538,739	4,666,892	7,205,631
Houston	2,326,707	5,508,016	7,834,723
Jackson	2,204,129	23,061,486	25,265,615
Jefferson	5,991,825	9,544,772	15,536,597
Lamar	3,136,190	8,197,102	11,333,292
Lauderdale	988,752	7,612,776	8,601,528
Lawrence	2,666,059	9,004,397	11,670,455
Lee	4,415,779	5,859,179	10,274,958
Limestone	202,804	6,918,303	7,121,107
Lowndes	3,627,596	6,694,217	10,321,813
Macon	4,092,398	8,069,972	12,162,370
Madison	1,263,239	9,322,233	10,585,472
Marengo	7,043,295	10,992,125	18,035,420
Marion	4,724,138	7,403,562	12,127,700
Marshall	1,768,034	7,500,323	9,268,357
Mobile	9,628,477	7,347,762	16,976,240
Monroe	10,398,725	13,141,634	23,540,359
Montgomery	2,663,309	7,703,394	10,366,703
Morgan	2,217,078	8,292,546	10,509,624
Perry	5,576,461	7,139,301	12,715,762
Pickens	6,688,133	11,700,305	18,388,438

Pike	3,095,893	5,841,141	8,937,034
Randolph	3,628,268	6,053,270	9,681,539
Russell	3,366,683	7,261,223	10,627,906
Shelby	3,476,308	8,621,011	12,097,319
St. Clair	4,578,716	9,118,195	13,696,911
Sumter	6,689,902	10,501,596	17,191,498
Talladega	4,454,108	7,050,997	11,505,106
Tallapoosa	4,715,313	8,073,767	12,789,081
Tuscaloosa	8,358,601	17,298,174	25,656,776
Walker	5,094,926	8,948,538	14,043,464
Washington	11,043,676	12,346,538	23,390,215
Wilcox	8,030,144	11,400,432	19,430,575
Winston	4,933,685	9,663,950	14,597,634
Total Alabama	321,419,390	575,536,224	896,955,614

Alabama Timber Volume by County

County	Softwood Live Timber Volume (oven-dry tons)	Hardwood Live Timber Volume (oven-dry tons)	Total Live Timber Volume (oven-dry tons)
Autauga	2,205,000	2,826,250	5,031,250
Baldwin	7,278,250	7,169,750	14,448,000
Barbour	5,187,000	4,802,000	9,989,000
Bibb	5,386,500	4,893,000	10,279,500
Blount	2,070,250	4,103,750	6,174,000
Bullock	2,861,250	3,050,250	5,911,500
Butler	5,152,000	3,556,000	8,708,000
Calhoun	2,185,750	3,839,500	6,025,250
Chambers	4,490,500	3,244,500	7,735,000
Cherokee	1,902,250	3,398,500	5,300,750
Chilton	1,450,750	3,395,000	4,845,750
Choctaw	9,184,000	6,258,000	15,442,000
Clarke	11,466,000	10,122,000	21,588,000
Clay	2,870,000	3,640,000	6,510,000
Cleburne	4,308,500	4,233,250	8,541,750
Coffee	2,583,000	2,196,250	4,779,250
Colbert	987,000	4,417,000	5,404,000
Conecuh	5,185,250	4,760,000	9,945,250
Coosa	3,979,500	3,507,000	7,486,500
Covington	5,866,000	3,641,750	9,507,750
Crenshaw	3,344,250	4,786,250	8,130,500
Cullman	1,604,750	4,320,750	5,925,500
Dale	3,013,500	4,508,000	7,521,500
Dallas	4,058,250	6,471,500	10,529,750

DeKalb	2,266,250	3,958,500	6,224,750
Elmore	2,035,250	4,009,250	6,044,500
Escambia	6,338,500	3,846,500	10,185,000
Etowah	1,078,000	4,653,250	5,731,250
Fayette	2,511,250	4,193,000	6,704,250
Franklin	1,051,750	4,123,000	5,174,750
Geneva	2,019,500	2,810,500	4,830,000
Greene	2,654,750	6,573,000	9,227,750
Hale	2,210,250	3,895,500	6,105,750
Henry	1,897,000	2,553,250	4,450,250
Houston	1,697,500	3,398,500	5,096,000
Jackson	1,408,750	12,351,500	13,760,250
Jefferson	3,997,000	4,987,500	8,984,500
Lamar	2,255,750	4,674,250	6,930,000
Lauderdale	645,750	3,902,500	4,548,250
Lawrence	1,967,000	4,754,750	6,721,750
Lee	3,162,250	3,370,500	6,532,750
Limestone	161,000	3,932,250	4,093,250
Lowndes	2,357,250	3,713,500	6,070,750
Macon	2,941,750	4,571,000	7,512,750
Madison	953,750	5,400,500	6,354,250
Marengo	5,304,250	6,018,250	11,322,500
Marion	3,139,500	3,554,250	6,693,750
Marshall	1,314,250	4,042,500	5,356,750
Mobile	6,823,250	4,128,250	10,951,500
Monroe	7,785,750	7,336,000	15,121,750
Montgomery	2,019,500	4,676,000	6,695,500
Morgan	1,757,000	4,676,000	6,433,000

Perry	3,865,750	3,781,750	7,647,500
Pickens	5,167,750	6,189,750	11,357,500
Pike	2,229,500	2,889,250	5,118,750
Randolph	2,516,500	3,041,500	5,558,000
Russell	2,276,750	4,210,500	6,487,250
Shelby	3,092,250	4,938,500	8,030,750
St. Clair	2,604,000	4,488,750	7,092,750
Sumter	5,034,750	5,801,250	10,836,000
Talladega	3,097,500	3,379,250	6,476,750
Tallapoosa	3,426,500	4,364,500	7,791,000
Tuscaloosa	5,792,500	9,651,250	15,443,750
Walker	3,479,000	4,529,000	8,008,000
Washington	8,100,750	7,133,000	15,233,750
Wilcox	5,916,750	6,069,000	11,985,750
Winston	3,475,500	4,852,750	8,328,250
Total Alabama	232,449,000	312,564,000	545,013,000

Alabama Annual Logging Residues by County

County	Softwood Logging Residues (oven-dry tons)	Hardwood Logging Residues (oven-dry tons)	Total Wood Logging Residues (oven-dry tons)
Autauga	11,935	13,440	25,375
Baldwin	42,490	27,353	69,843
Barbour	27,703	22,908	50,610
Bibb	28,788	35,315	64,103
Blount	34,790	12,198	46,988
Bullock	13,318	13,090	26,408
Butler	22,278	26,513	48,790
Calhoun	7,333	6,055	13,388
Chambers	17,115	12,320	29,435
Cherokee	5,040	10,028	15,068
Chilton	12,373	20,685	33,058
Choctaw	46,970	54,250	101,220
Clarke	76,248	55,668	131,915
Clay	16,993	22,750	39,743
Cleburne	11,148	9,678	20,825
Coffee	19,495	9,293	28,788
Colbert	4,025	17,255	21,280
Conecuh	36,505	24,658	61,163
Coosa	12,145	14,560	26,705
Covington	31,308	16,188	47,495
Crenshaw	22,925	23,923	46,848
Cullman	13,983	10,763	24,745
Dale	9,345	12,180	21,525
Dallas	16,625	24,500	41,125
DeKalb	4,165	7,928	12,093

Elmore	4,393	15,383	19,775
Escambia	36,365	12,215	48,580
Etowah	8,523	13,598	22,120
Fayette	15,208	24,868	40,075
Franklin	8,488	17,168	25,655
Geneva	5,285	6,860	12,145
Greene	17,395	22,225	39,620
Hale	14,000	11,375	25,375
Henry	13,720	12,495	26,215
Houston	2,170	4,883	7,053
Jackson	4,358	17,430	21,788
Jefferson	14,963	17,238	32,200
Lamar	14,753	32,410	47,163
Lauderdale	2,240	9,730	11,970
Lawrence	4,235	7,018	11,253
Lee	18,778	11,323	30,100
Limestone	1,523	10,063	11,585
Lowndes	16,905	18,200	35,105
Macon	12,215	11,795	24,010
Madison	770	8,103	8,873
Marengo	25,428	56,770	82,198
Marion	11,008	13,423	24,430
Marshall	2,940	5,093	8,033
Mobile	16,660	19,898	36,558
Monroe	55,860	54,810	110,670
Montgomery	28,053	29,680	57,733
Morgan	5,723	7,490	13,213
Perry	12,565	14,560	27,125
Pickens	27,143	48,318	75,460

Pike	21,735	19,075	40,810
Randolph	18,375	15,715	34,090
Russell	16,660	14,123	30,783
Shelby	10,028	10,203	20,230
St. Clair	19,058	8,435	27,493
Sumter	43,523	26,320	69,843
Talladega	17,553	20,108	37,660
Tallapoosa	20,703	30,958	51,660
Tuscaloosa	30,695	49,053	79,748
Walker	24,570	56,403	80,973
Washington	38,535	38,273	76,808
Wilcox	24,798	25,095	49,893
Winston	15,138	17,150	32,288
Total Alabama	1,248,065	1,368,815	2,616,880

Alabama Rough Tree Volume by County

County	Softwood Rough Tree Volume (oven-dry tons)	Hardwood Rough Tree Volume (oven-dry tons)	Total Rough Tree Volume (oven-dry tons)
Autauga	94,500	277,253	371,753
Baldwin	110,128	1,808,573	1,918,700
Barbour	716,923	765,503	1,482,425
Bibb	90,038	484,750	574,788
Blount	40,390	476,735	517,125
Bullock	495,548	658,893	1,154,440
Butler	328,055	693,018	1,021,073
Calhoun	45,045	583,083	628,128
Chambers	577,010	751,450	1,328,460
Cherokee	211,383	446,058	657,440
Chilton	77,858	413,805	491,663
Choctaw	141,190	578,883	720,073
Clarke	211,295	1,309,595	1,520,890
Clay	19,793	679,560	699,353
Cleburne	36,505	603,698	640,203
Coffee	82,758	372,173	454,930
Colbert	31,553	670,215	701,768
Conecuh	176,330	830,708	1,007,038
Coosa	24,570	279,755	304,325
Covington	151,743	484,400	636,143
Crenshaw	58,450	501,533	559,983
Cullman	48,335	648,638	696,973
Dale	50,680	528,518	579,198
Dallas	146,125	898,083	1,044,208

DeKalb	337,278	609,998	947,275
Elmore	12,775	305,025	317,800
Escambia	16,415	350,403	366,818
Etowah	113,138	757,748	870,886
Fayette	28,735	406,945	435,680
Franklin	83,930	536,620	620,550
Geneva	156,818	522,585	679,403
Greene	213,378	842,783	1,056,160
Hale	42,333	483,910	526,243
Henry	46,778	274,225	321,003
Houston	23,660	455,175	478,835
Jackson	304,483	1,435,718	1,740,200
Jefferson	70,280	695,695	765,975
Lamar	72,888	624,313	697,200
Lauderdale	60,113	411,653	471,765
Lawrence	130,113	580,825	710,938
Lee	540,313	681,046	1,221,358
Limestone	2,223	464,310	466,533
Lowndes	69,143	900,690	969,833
Macon	148,838	780,535	929,373
Madison	64,278	734,718	798,996
Marengo	145,128	618,888	764,015
Marion	145,425	549,588	695,013
Marshall	58,993	542,360	601,353
Mobile	147,735	1,386,788	1,534,523
Monroe	120,698	1,337,700	1,458,398
Montgomery	276,325	859,198	1,135,523
Morgan	71,103	489,318	560,420

Perry	184,853	753,795	938,648
Pickens	87,290	813,855	901,145
Pike	354,935	800,625	1,155,560
Randolph	142,625	727,458	870,083
Russell	476,875	576,730	1,053,605
Shelby	39,795	456,435	496,230
St. Clair	72,293	490,595	562,888
Sumter	356,195	627,235	983,430
Talladega	42,298	382,690	424,988
Tallapoosa	21,508	519,908	541,415
Tuscaloosa	176,068	1,197,963	1,374,030
Walker	148,190	466,078	614,268
Washington	186,673	1,414,630	1,601,303
Wilcox	220,885	487,760	708,645
Winston	180,250	519,330	699,580
Total Alabama	10,160,238	44,618,712	54,778,950

Alabama Annual Rough Tree Harvest by County

County	Softwood Rough Tree Harvests (oven-dry tons)	Hardwood Rough Tree Harvests (oven-dry tons)	Total Rough Tree Harvests (oven-dry tons)
Autauga	4,725	13,863	18,588
Baldwin	5,506	90,429	95,935
Barbour	35,846	38,275	74,121
Bibb	4,502	24,238	28,739
Blount	2,020	23,837	25,856
Bullock	24,777	32,945	57,722
Butler	16,403	34,651	51,054
Calhoun	2,252	29,154	31,406
Chambers	28,851	37,573	66,423
Cherokee	10,569	22,303	32,872
Chilton	3,893	20,690	24,583
Choctaw	7,060	28,944	36,004
Clarke	10,565	65,480	76,045
Clay	990	33,978	34,968
Cleburne	1,825	30,185	32,010
Coffee	4,138	18,609	22,747
Colbert	1,578	33,511	35,088
Conecuh	8,817	41,535	50,352
Coosa	1,229	13,988	15,216
Covington	7,587	24,220	31,807
Crenshaw	2,923	25,077	27,999
Cullman	2,417	32,432	34,849
Dale	2,534	26,426	28,960
Dallas	7,306	44,904	52,210

DeKalb	16,864	30,500	47,364
Elmore	639	15,251	15,890
Escambia	821	17,520	18,341
Etowah	5,657	37,887	43,544
Fayette	1,437	20,347	21,784
Franklin	4,197	26,831	31,028
Geneva	7,841	26,129	33,970
Greene	10,669	42,139	52,808
Hale	2,117	24,196	26,312
Henry	2,339	13,711	16,050
Houston	1,183	22,759	23,942
Jackson	15,224	71,786	87,010
Jefferson	3,514	34,785	38,299
Lamar	3,644	31,216	34,860
Lauderdale	3,006	20,583	23,588
Lawrence	6,506	29,041	35,547
Lee	27,016	34,052	61,068
Limestone	111	23,216	23,327
Lowndes	3,457	45,035	48,492
Macon	7,442	39,027	46,469
Madison	3,214	36,736	39,950
Marengo	7,256	30,944	38,201
Marion	7,271	27,479	34,751
Marshall	2,950	27,118	30,068
Mobile	7,387	69,339	76,726
Monroe	6,035	66,885	72,920
Montgomery	13,816	42,960	56,776
Morgan	3,555	24,466	28,021

Perry	9,243	37,690	46,932
Pickens	4,365	40,693	45,057
Pike	17,747	40,031	57,778
Randolph	7,131	36,373	43,504
Russell	23,844	28,837	52,680
Shelby	1,990	22,822	24,812
St. Clair	3,615	24,530	28,144
Sumter	17,810	31,362	49,172
Talladega	2,115	19,135	21,249
Tallapoosa	1,075	25,995	27,071
Tuscaloosa	8,803	59,898	68,702
Walker	7,410	23,304	30,713
Washington	9,334	70,732	80,065
Wilcox	11,044	24,388	35,432
Winston	9,013	25,967	34,979
Total Alabama	508,012	2,230,936	2,738,947

Alabama Annual Whole Tree Chips by County

County	Softwood Dirty Chips (oven-dry tons)	Hardwood Dirty Chips (oven-dry tons)	Total Wood Dirty Chips (oven-dry tons)
Autauga	16,660	27,303	43,963
Baldwin	47,996	117,781	165,778
Barbour	63,549	61,183	124,731
Bibb	33,289	59,553	92,842
Blount	36,810	36,034	72,844
Bullock	38,095	46,035	84,130
Butler	38,680	61,163	99,844
Calhoun	9,585	35,209	44,794
Chambers	45,966	49,893	95,858
Cherokee	15,609	32,330	47,940
Chilton	16,265	41,375	57,641
Choctaw	54,030	83,194	137,224
Clarke	86,812	121,147	207,960
Clay	17,982	56,728	74,710
Cleburne	12,973	39,862	52,835
Coffee	23,633	27,901	51,534
Colbert	5,603	50,766	56,368
Conecuh	45,322	66,193	111,514
Coosa	13,374	28,548	41,921
Covington	38,895	40,408	79,302
Crenshaw	25,848	48,999	74,847
Cullman	16,399	43,194	59,594
Dale	11,879	38,606	50,485
Dallas	23,931	69,404	93,335

DeKalb	21,029	38,427	59,456
Elmore	5,031	30,634	35,665
Escambia	37,186	29,735	66,921
Etowah	14,179	51,485	65,664
Fayette	16,644	45,215	61,859
Franklin	12,684	43,999	56,683
Geneva	13,126	32,989	46,115
Greene	28,064	64,364	92,428
Hale	16,117	35,571	51,687
Henry	16,059	26,206	42,265
Houston	3,353	27,641	30,994
Jackson	19,582	89,216	108,798
Jefferson	18,477	52,022	70,499
Lamar	18,397	63,626	82,023
Lauderdale	5,246	30,313	35,558
Lawrence	10,741	36,059	46,799
Lee	45,793	45,375	91,168
Limestone	1,634	33,278	34,912
Lowndes	20,362	63,235	83,597
Macon	19,657	50,822	70,479
Madison	3,984	44,838	48,822
Marengo	32,684	87,714	120,398
Marion	18,279	40,902	59,181
Marshall	5,890	32,211	38,100
Mobile	24,047	89,237	113,284
Monroe	61,895	121,695	183,590
Montgomery	41,869	72,640	114,509
Morgan	9,278	31,956	41,234

Perry	21,808	52,250	74,057
Pickens	31,507	89,010	120,517
Pike	39,482	59,106	98,588
Randolph	25,506	52,088	77,594
Russell	40,504	42,959	83,463
Shelby	12,017	33,024	45,042
St. Clair	22,672	32,965	55,637
Sumter	61,332	57,682	119,014
Talladega	19,667	39,242	58,909
Tallapoosa	21,778	56,953	78,731
Tuscaloosa	39,498	108,951	148,449
Walker	31,980	79,706	111,686
Washington	47,869	109,004	156,873
Wilcox	35,842	49,483	85,325
Winston	24,150	43,117	67,267
Total Alabama	1,756,077	3,599,751	5,355,827

Alabama Primary Wood Residue Volume by County

County	Bark (oven-dry tons)	Coarse Residues (oven-dry tons)	Fine Residues (oven-dry tons)	Total Primary Wood Residues (oven-dry tons)
Autauga	84,138	27,561	13,099	124,797
Baldwin	26,180	18,360	11,675	56,214
Barbour	17,105	23,578	35,472	76,154
Bibb	128,430	109,975	35,350	273,755
Blount	1,518	5,040	1,828	8,385
Bullock	521	1,442	741	2,704
Butler	38,984	127,610	121,079	287,673
Calhoun	1,962	6,759	6,276	14,996
Chambers	12,651	22,500	40,478	75,629
Cherokee	14	47	28	88
Chilton	43,918	146,293	139,945	330,155
Choctaw	7,831	5,640	3,261	16,732
Clarke	9,572	21,490	29,039	60,100
Clay	3,610	5,500	9,154	18,264
Cleburne	1,112	3,052	1,075	5,239
Coffee	1,472	2,953	1,250	5,674
Colbert	3,857	10,580	8,203	22,639
Conecuh	10,025	31,387	29,440	70,852
Coosa	3,769	7,122	8,328	19,219
Covington	1,005	2,625	2,165	5,795
Crenshaw	7,008	18,173	17,204	42,385
Cullman	3,692	15,592	9,929	29,213
Dale	27	85	55	167
Dallas	20,148	31,215	61,688	113,050
DeKalb	1,998	3,500	4,306	9,804
Elmore	713	2,465	1,673	4,850
Escambia	188,002	110,989	61,132	360,122
Etowah	1,023	3,000	3,272	7,294

Fayette	18,679	63,779	58,728	141,186
Franklin	5,078	13,053	3,888	22,019
Geneva	107,631	77,508	33,879	219,017
Greene	1,795	4,500	5,444	11,739
Hale	1,551	5,972	2,647	10,170
Henry	12,514	40,742	38,676	91,932
Houston	2,128	4,000	6,456	12,584
Jackson	56,981	12,544	12,504	82,028
Jefferson	1,213	2,428	1,727	5,367
Lamar	41,304	147,581	130,368	319,253
Lauderdale	1,579	2,000	3,404	6,983
Lawrence	157,294	0	0	157,294
Lee	30,341	104,197	95,352	229,890
Limestone	2,290	5,712	1,679	9,680
Lowndes	6,853	23,612	13,389	43,854
Macon	705	1,473	649	2,827
Madison	4,378	8,735	12,872	25,985
Marengo	35,899	40,864	30,264	107,026
Marion	5,281	26,253	12,486	44,019
Marshall	25,339	139,935	79,450	244,724
Mobile	173,072	161,694	152,291	487,056
Monroe	193,566	98,536	111,565	403,666
Montgomery	7,841	26,114	7,987	41,942
Morgan	2,761	3,825	8,662	15,248
Perry	2,446	6,553	1,341	10,340
Pickens	29,760	51,499	77,824	159,083
Pike	1,233	3,234	2,657	7,124
Randolph	378	1,019	808	2,205
Russell	245,883	114,000	104,555	464,438
Shelby	16,958	51,490	32,227	100,675
St. Clair	2,113	7,193	3,582	12,888
Sumter	4,884	4,000	14,818	23,702
Talladega	136,956	93,559	10,250	240,764

Tallapoosa	489	1,834	1,227	3,549
Tuscaloosa	68,334	222,647	204,222	495,202
Walker	17,282	59,150	53,892	130,324
Washington	4,158	10,125	8,640	22,923
Wilcox	18,486	62,636	58,935	140,056
Winston	29,606	48,573	85,569	163,747
Total Alabama	2,095,309	2,517,089	2,142,067	6,754,464

Alabama Secondary Wood Residue Volume by County

County	Misc. Wood Residue (oven-dry tons)
Autauga	4,066
Baldwin	10,973
Barbour	4,470
Bibb	3,847
Blount	8,775
Bullock	0
Butler	5,005
Calhoun	9,196
Chambers	1,312
Cherokee	1,887
Chilton	11,603
Choctaw	2,317
Clarke	7,527
Clay	9,113
Cleburne	1,039
Coffee	2,840
Colbert	5,757
Conecuh	4,177
Coosa	3,281
Covington	2,875
Crenshaw	1,336
Cullman	12,197
Dale	2,934
Dallas	4,691
DeKalb	4,818

Elmore	6,574
Escambia	3,187
Etowah	8,612
Fayette	1,975
Franklin	22,335
Geneva	963
Greene	3,439
Hale	1,624
Henry	6,980
Houston	7,523
Jackson	5,073
Jefferson	32,518
Lamar	4,476
Lauderdale	20,071
Lawrence	1,598
Lee	6,908
Limestone	2,925
Lowndes	627
Macon	629
Madison	11,978
Marengo	3,754
Marion	46,632
Marshall	20,673
Mobile	29,724
Monroe	3,154
Montgomery	18,478
Morgan	12,847
Perry	0
Pickens	1,945

Pike	6,585
Randolph	3,188
Russell	1,009
Shelby	10,045
St. Clair	1,580
Sumter	5,765
Talladega	8,471
Tallapoosa	1,944
Tuscaloosa	12,540
Walker	7,191
Washington	713
Wilcox	2,837
Winston	48,669
Total Alabama	523,800

Alabama Total Residual Woody Biomass by County

County	Secondary Residuals (oven-dry tons)	Primary Resid.-Bark (oven-dry tons)	Primary Resid.-Coarse (oven-dry tons)	Primary Resid.-Fine (oven-dry tons)	Whole-Tree Chips (oven-dry tons)	Total Residual Woody Biomass (oven-dry tons)
Autauga	4,066	84,138	27,561	13,099	43,963	172,826
Baldwin	10,973	26,180	18,360	11,675	165,778	232,965
Barbour	4,470	17,105	23,578	35,472	124,731	205,355
Bibb	3,847	128,430	109,975	35,350	92,842	370,444
Blount	8,775	1,518	5,040	1,828	72,844	90,004
Bullock	0	521	1,442	741	84,130	86,833
Butler	5,005	38,984	127,610	121,079	99,844	392,522
Calhoun	9,196	1,962	6,759	6,276	44,794	68,986
Chambers	1,312	12,651	22,500	40,478	95,858	172,799
Cherokee	1,887	14	47	28	47,940	49,914
Chilton	11,603	43,918	146,293	139,945	57,641	399,399
Choctaw	2,317	7,831	5,640	3,261	137,224	156,273
Clarke	7,527	9,572	21,490	29,039	207,960	275,587
Clay	9,113	3,610	5,500	9,154	74,710	102,087
Cleburne	1,039	1,112	3,052	1,075	52,835	59,113
Coffee	2,840	1,472	2,953	1,250	51,534	60,048
Colbert	5,757	3,857	10,580	8,203	56,368	84,765
Conecuh	4,177	10,025	31,387	29,440	111,514	186,544
Coosa	3,281	3,769	7,122	8,328	41,921	64,421
Covington	2,875	1,005	2,625	2,165	79,302	87,972
Crenshaw	1,336	7,008	18,173	17,204	74,847	118,567

Cullman	12,197	3,692	15,592	9,929	59,594	101,004
Dale	2,934	27	85	55	50,485	53,586
Dallas	4,691	20,148	31,215	61,688	93,335	211,077
DeKalb	4,818	1,998	3,500	4,306	59,456	74,078
Elmore	6,574	713	2,465	1,673	35,665	47,089
Escambia	3,187	188,002	110,989	61,132	66,921	430,230
Etowah	8,612	1,023	3,000	3,272	65,664	81,571
Fayette	1,975	18,679	63,779	58,728	61,859	205,019
Franklin	22,335	5,078	13,053	3,888	56,683	101,037
Geneva	963	107,631	77,508	33,879	46,115	266,095
Greene	3,439	1,795	4,500	5,444	92,428	107,606
Hale	1,624	1,551	5,972	2,647	51,687	63,481
Henry	6,980	12,514	40,742	38,676	42,265	141,176
Houston	7,523	2,128	4,000	6,456	30,994	51,102
Jackson	5,073	56,981	12,544	12,504	108,798	195,899
Jefferson	32,518	1,213	2,428	1,727	70,499	108,384
Lamar	4,476	41,304	147,581	130,368	82,023	405,751
Lauderdale	20,071	1,579	2,000	3,404	35,558	62,612
Lawrence	1,598	157,294	0	0	46,799	205,691
Lee	6,908	30,341	104,197	95,352	91,168	327,967
Limestone	2,925	2,290	5,712	1,679	34,912	47,517
Lowndes	627	6,853	23,612	13,389	83,597	128,078
Macon	629	705	1,473	649	70,479	73,935
Madison	11,978	4,378	8,735	12,872	48,822	86,785
Marengo	3,754	35,899	40,864	30,264	120,398	231,179

Marion	46,632	5,281	26,253	12,486	59,181	149,832
Marshall	20,673	25,339	139,935	79,450	38,100	303,497
Mobile	29,724	173,072	161,694	152,291	113,284	630,063
Monroe	3,154	193,566	98,536	111,565	183,590	590,410
Montgomery	18,478	7,841	26,114	7,987	114,509	174,929
Morgan	12,847	2,761	3,825	8,662	41,234	69,329
Perry	0	2,446	6,553	1,341	74,057	84,397
Pickens	1,945	29,760	51,499	77,824	120,517	281,546
Pike	6,585	1,233	3,234	2,657	98,588	112,297
Randolph	3,188	378	1,019	808	77,594	82,987
Russell	1,009	245,883	114,000	104,555	83,463	548,910
Shelby	10,045	16,958	51,490	32,227	45,042	155,761
St. Clair	1,580	2,113	7,193	3,582	55,637	70,105
Sumter	5,765	4,884	4,000	14,818	119,014	148,482
Talladega	8,471	136,956	93,559	10,250	58,909	308,144
Tallapoosa	1,944	489	1,834	1,227	78,731	84,225
Tuscaloosa	12,540	68,334	222,647	204,222	148,449	656,191
Walker	7,191	17,282	59,150	53,892	111,686	249,202
Washington	713	4,158	10,125	8,640	156,873	180,509
Wilcox	2,837	18,486	62,636	58,935	85,325	228,218
Winston	48,669	29,606	48,573	85,569	67,267	279,683
Total Alabama	523,800	2,095,309	2,517,089	2,142,067	5,355,827	12,634,092

Appendix B
Project Investment Analyses

Base Case Investment Analysis
Woody Biomass Fuel = $20/o.d. ton

Case F Sheet 5 (4)		TALLC Synthesis Gas Plant			
Wood Cost $/Green Ton = $10.00		18.1 od tph Single Commerical Size Train			
		Electric Power Generation Equivalent MW		38.72	
ROI no Tax Credits = +6.0%		Synthesis Gas fed to Combined Cycle Power Plant			
Items	**Heat Rate Btu/kwh**	**20 yr average price**	**units**	**units/year**	**Annual Revenue**
Syn Gas CCPP Power Plants		$4.11	per mmBtu	1,870,838	$7,690,646
Total Sales					$7,690,646
Natural Gas Supply Cost		$4.11	per mmBtu	-	$0
Green Wood Supply Cost		$10.00	per ton	288,720	$2,887,200
Electric Power Cost		$0.0439	$/kwh	13,529,456	$594,315
Other operating Costs					$4,293,380
Total Costs					$7,774,895
Income before credits					-$84,249
Non Tax Credit pass thru to investors Interest and principal payment					$1,521,890
Net before Tax credit					$1,437,640
ROI before Tax Credits and grants					6.0%
Tax Credits Syn Gas CCPP	6,040	$0.019	per kwh	309,741,407	$5,900,636
Agr Grant Wood Sect 808		$5.19	per ton	288,720	$1,498,457
Total Tax Credits & Grants					$7,399,093
ROI after Tax Credits and grants					37.1%
Greenhouse Gas Allowances compared to Coal Fired Power Plant				units/yr saved	
SO2 Coal at 1.08% sulfur		$104	per ton	3,512	$365,289
NOX Gas Turbines at 9 ppm		$2,253	per ton	239	$538,721
CO2 Wood-Carbon Sequestration		$94	per ton	75,847	$7,129,594
Wildfire (Wood) Mercury Pollution Hi		$200,000	per ton	0.005551	$1,110
Greenhouse Gas Credits					$8,034,714
Total Credits					$15,433,807
Total Credits & Allowances Plus Pass Thru to Partners					$16,871,447
Cash Investment					$23,826,880
ROI after all Tax Credits, grants and allowances					71%
Project Payout Months					17
Forestry employment		60	people		
Gas Plant employment		25	people		
Total employment		85	people		
State of Alabama Incentive Package		$126,400	per employee		$10,744,000
Portfolio can be any size or mix that generates Taxable Income that can be offset with above Tax Credits			Years Depreciation	30	
Fuel and Power Prices YTD (Jan to Aug) 2001, Electric Power Monthly December 2001 Energy Information Administration EIA/DOE					
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Source: Tourtellotte & Associates LLC

Alternative Investment Analysis
Woody Biomass Fuel = $30/o.d. ton

Case F Sheet 5 Breakeven **TALLC Synthesis Gas Plant**

Wood Cost $/Green Ton = $14.95 **18.1 od tph Single Commerical Size Train**

Electric Power Generation Equivalent MW 38.72

Synthesis Gas fed to Combined Cycle Power Plant

Items	Heat Rate Btu/kwh	20 yr average price	units	units/year	Annual Revenue
Syn Gas CCPP Power Plants		$4.11	per mmBtu	1,870,838	$7,690,646
Total Sales					$7,690,646
Natural Gas Supply Cost		$4.11	per mmBtu	-	$0
Green Wood Supply Cost		$14.95	per ton	288,720	$4,316,364
Electric Power Cost		$0.0439	$/kwh	13,529,456	$594,315
Other operating Costs					$4,293,380
Total Costs					$9,204,059
Income before credits					-$1,513,413
Non Tax Credit pass thru to investors Interest and principal payment					$1,521,890
Net before Tax credit					$8,476
ROI before Tax Credits and grants					0.0%
Tax Credits Syn Gas CCPP	6,040	$0.019	per kwh	309,741,407	$5,900,636
Agr Grant Wood Sect 808		$5.19	per ton	288,720	$1,498,457
Total Tax Credits & Grants					$7,399,093
ROI after Tax Credits and grants					31.1%
Greenhouse Gas Allowances compared to Coal Fired Power Plant				units/yr saved	
SO2 Coal at 1.08% sulfur		$104	per ton	3,512	$365,289
NOX Gas Turbines at 9 ppm		$2,253	per ton	239	$538,721
CO2 Wood-Carbon Sequestration		$94	per ton	75,847	$7,129,594
Wildfire (Wood) Mercury Pollution Hi		$200,000	per ton	0.005551	$1,110
Greenhouse Gas Credits					$8,034,714
Total Credits					$15,433,807
Total Credits & Allowances Plus Pass Thru to Partners					$15,442,283
Cash Investment					$23,826,880
ROI after all Tax Credits, grants and allowances					65%
Project Payout Months					19
Forestry employment		60	people		
Gas Plant employment		25	people		
Total employment		85	people		
State of Alabama Incentive Package		$126,400	per employee		$10,744,000
Portfolio can be any size or mix that generates Taxable Income that can be offset with above Tax Credits			Years Depreciation	30	
Fuel and Power Prices YTD (Jan to Aug) 2001, Electric Power Monthly December 2001 Energy Information Administration EIA/DOE					
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Source: Tourtellotte & Associates LLC

Alternative Investment Analysis
Woody Biomass Fuel = $40/o.d. ton

Case F Sheet 5 (2) **TALLC Synthesis Gas Plant**

Wood Cost $/Green Ton = $20.00 **18.1 od tph Single Commerical Size Train**

Electric Power Generation Equivalent MW 38.72

ROI no Tax Credits = -6.1% **Synthesis Gas fed to Combined Cycle Power Plant**

Items	Heat Rate Btu/kwh	20 yr average price	units	units/year	Annual Revenue
Syn Gas CCPP Power Plants		$4.11	per mmBtu	1,870,838	$7,690,646
Total Sales					$7,690,646
Natural Gas Supply Cost		$4.11	per mmBtu	-	$0
Green Wood Supply Cost		$20.00	per ton	288,720	$5,774,400
Electric Power Cost		$0.0439	$/kwh	13,529,456	$594,315
Other operating Costs					$4,293,380
Total Costs					$10,662,095
Income before credits					-$2,971,449
Non Tax Credit pass thru to investors Interest and principal payment					$1,521,890
Net before Tax credit					-$1,449,560
ROI before Tax Credits and grants					-6.1%
Tax Credits Syn Gas CCPP	6,040	$0.019	per kwh	309,741,407	$5,900,636
Agr Grant Wood Sect 808		$5.19	per ton	288,720	$1,498,457
Total Tax Credits & Grants					$7,399,093
ROI after Tax Credits and grants					25.0%
Greenhouse Gas Allowances compared to Coal Fired Power Plant				units/yr saved	
SO2 Coal at 1.08% sulfur		$104	per ton	3,512	$365,289
NOX Gas Turbines at 9 ppm		$2,253	per ton	239	$538,721
CO2 Wood-Carbon Sequestration		$94	per ton	75,847	$7,129,594
Wildfire (Wood) Mercury Pollution Hi		$200,000	per ton	0.005551	$1,110
Greenhouse Gas Credits					$8,034,714
Total Credits					$15,433,807
Total Credits & Allowances Plus Pass Thru to Partners					$13,984,247
Cash Investment					$23,826,880
ROI after all Tax Credits, grants and allowances					59%
Project Payout Months					20
Forestry employment		60	people		
Gas Plant employment		25	people		
Total employment		85	people		
State of Alabama Incentive Package		$126,400	per employee		$10,744,000
Portfolio can be any size or mix that generates Taxable Income that can be offset with above Tax Credits			Years Depreciation	30	
Fuel and Power Prices YTD (Jan to Aug) 2001, Electric Power Monthly December 2001 Energy Information Administration EIA/DOE					
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Source: Tourtellotte & Associates LLC

Alternative Investment Analysis
Woody Biomass Fuel = $50/o.d. ton

Case F Sheet 5 (3) — **TALLC Synthesis Gas Plant**

Wood Cost $/Green Ton = $25.00 — **18.1 od tph Single Commerical Size Train**

Electric Power Generation Equivalent MW 38.72

ROI no Tax Credits = -12.1% — **Synthesis Gas fed to Combined Cycle Power Plant**

Items	Heat Rate Btu/kwh	20 yr average price	units	units/year	Annual Revenue
Syn Gas CCPP Power Plants		$4.11	per mmBtu	1,870,838	$7,690,646
Total Sales					$7,690,646
Natural Gas Supply Cost		$4.11	per mmBtu	-	$0
Green Wood Supply Cost		$25.00	per ton	288,720	$7,218,000
Electric Power Cost		$0.0439	$/kwh	13,529,456	$594,315
Other operating Costs					$4,293,380
Total Costs					$12,105,695
Income before credits					-$4,415,049
Non Tax Credit pass thru to investors Interest and principal payment					$1,521,890
Net before Tax credit					-$2,893,160
ROI before Tax Credits and grants					-12.1%
Tax Credits Syn Gas CCPP	6,040	$0.019	per kwh	309,741,407	$5,900,636
Agr Grant Wood Sect 808		$5.19	per ton	288,720	$1,498,457
Total Tax Credits & Grants					$7,399,093
ROI after Tax Credits and grants					18.9%
Greenhouse Gas Allowances compared to Coal Fired Power Plant				units/yr saved	
SO2 Coal at 1.08% sulfur		$104	per ton	3,512	$365,289
NOX Gas Turbines at 9 ppm		$2,253	per ton	239	$538,721
CO2 Wood-Carbon Sequestration		$94	per ton	75,847	$7,129,594
Wildfire (Wood) Mercury Pollution Hi		$200,000	per ton	0.005551	$1,110
Greenhouse Gas Credits					$8,034,714
Total Credits					$15,433,807
Total Credits & Allowances Plus Pass Thru to Partners					$12,540,647
Cash Investment					$23,826,880
ROI after all Tax Credits, grants and allowances					53%
Project Payout Months					23
Forestry employment		60	people		
Gas Plant employment		25	people		
Total employment		85	people		
State of Alabama Incentive Package		$126,400	per employee		$10,744,000

Portfolio can be any size or mix that generates Taxable Income that can be offset with above Tax Credits — Years Depreciation 30

Fuel and Power Prices YTD (Jan to Aug) 2001, Electric Power Monthly December 2001 Energy Information Administration EIA/DOE

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Source: Tourtellotte & Associates LLC

Appendix C
Biomass Energy Glossary

A

***Activated Sludge Process*:** A biological waste-water treatment process in which a mixture of waste water and activated sludge is agitated and aerated. The activated sludge is then separated from the treated wastewater by sedimentation and disposed of or returned to the process as needed.

***Anaerobic Digestion*:** A biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other by-products.

***Annual Growth*:** The average annual increase in the biomass of growing stock trees on a specified area.

Annual Removal: The average annual biomass of growing stock trees removed by harvesting or other forest management operations on a specified area.

B

Backup Rate: A utility charge for providing occasional electricity service to replace on-site generation.

Baghouse: A chamber containing fabric filter bags that remove particles from furnace stack exhaust gases. Used to eliminate particles greater than 20 microns in diameter.

Barrel: A volumetric unit of measure for crude oil and petroleum products equivalent to 42 gallons.

***Barrel of Oil Equivalent*:** A unit of energy equal to the amount of energy contained in a barrel of crude oil. Approximately 5.78 million Btu or 1,700 kWh.

Baseload Capacity: The power output that generating equipment can continuously produce.

BCF: Billion cubic feet.

Biochemical Conversion Process: The use of living organisms or their products to convert organic material to fuels.

Biodegradable: Capable of decomposing rapidly under natural conditions.

Biodiesel: A biofuel produced through transesterification, a process in which organically- derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. The biomass - derived ethyl or methyl esters can be blended with conventional diesel fuel or used as a neat fuel (100% biodiesel). Biodiesel can be made from soybean or rapeseed oils, animal fats, waste vegetable oils, or microalgae oils.

Bioenergy: Useful, renewable energy produced from organic matter. The conversion of the complex carbohydrates in organic matter to energy. Organic matter may either be used directly as a fuel or processed into liquid or gaseous fuels, or other solid fuel forms.

Biofuels: Fuels made from cellulosic biomass resources. Biofuels include ethanol, biodiesel, and methanol.

Biogas: A combustible gas derived from decomposing biological waste. Biogas normally consists of 50 to 60 percent methane.

Biological Assessment: A specific process required as part of an environmental assessment. An evaluation of potential effects of a proposed project on proposed, endangered, threatened, and sensitive animal and plant species and their habitats.

Biomass: Organic matter available on a renewable basis. Biomass includes forest and mill residues, agricultural crops and wastes, wood and wood wastes, animal wastes, live-stock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.

Biomass Fuel: Liquid, solid, or gaseous fuel produced by conversion of biomass.

Biomass Energy: See Bioenergy.

Black Liquor: A by-product of paper production, which can be used as fuel to power the plant.

Board Feet (BF): Unit of measure for logs and lumber. One board foot is equivalent to a piece of wood 1 inch thick, 12 inches wide, and 12 inches long.

Boiler: Any device used to burn biomass fuel to heat water for generating steam.

Boiler Fuel: An energy source to produce heat that is transferred to the boiler vessel in order to generate steam or hot water. Fossil fuels are the primary energy sources used to produce heat for boilers.

Boiler Horsepower: A measure of the maximum rate of heat energy output of a steam generator. One boiler horsepower equals 33,480 Btu/hr output in steam.

British Thermal Unit:(BTU): A unit of heat energy equal to the heat needed to raise the temperature of one pound of water from 60°F to 61°F at one atmospheric pressure.

C

Cunit (CCF): One hundred cubic feet of solid wood. Used as a log measure or as a measure of solid wood content. 1 CCF contains typically 1.4 BDT.

Capacity: The maximum power that a machine or system can produce or carry safely. The maximum instantaneous output of a resource under specified conditions. The capacity of generating equipment is generally expressed in kilowatts or megawatts.

Capacity Factor: (1) The ratio of the average load on a generating resource to its capacity rating during a specified period of time. (2) The amount of energy that the system produces at a particular site as a percentage of the total amount that it would produce if it operated at rated capacity during the entire year.

Capital Cost: The total investment needed to complete a project and bring it to a commercially operable status. The cost of construction of a new plant. The expenditures for the purchase or acquisition of existing facilities.

Carbohydrate: A chemical compound made up of carbon, hydrogen, and oxygen. Includes sugars, cellulose, and starches.

Centralized Sewage Treatment: The collection and treatment of sewage from many sources to remove pollutants and pathogens.

Char: The remains of solid biomass that has been incompletely combusted, such as charcoal if wood is incompletely burned.

Chipper: A machine that produces wood chips by knife action.

Chips: Woody material cut into short, thin wafers. Chips are used as a raw material for pulping and fiberboard or as biomass fuel.

Class I Area: Any area designated for the most stringent protection from future air quality degradation.

Class II Area: Any area where air is cleaner than required by federal air quality standards and designated for a moderate degree of protection from air quality degradation. Moderate increases in new pollution may be permitted in Class II areas.

Clean Air Act: National law establishing ambient air quality emission standards to be implemented by participating states.

Clean Alternative Fuel: Any fuel (including methanol, ethanol, or other alcohols or any mixture thereof containing 85 percent or more by volume of such alcohol with gasoline or other fuel), reformulated gasoline, diesel, natural gas, liquefied petroleum gas, and hydrogen) or power source (including electricity) used in a clean-fueled vehicle that complies with the standards and requirements of the Clean Air Act Amendments of 1990.

Cofiring: Concurrent burning of two different fuels in a boiler. Cofiring of biomass with fossil fuels has been found to reduce greenhouse gas emissions.

Cogeneration: The sequential production of electricity and useful thermal energy from a common fuel source. Reject heat from industrial processes can be used to power an electric generator (bottoming cycle). Conversely, surplus heat from an electric generating plant can be used for industrial processes, or space and water heating purposes (topping cycle).

Combustion Gases: The gases released from a combustion process.

Commercial Forest Land: Forested land which is capable of producing new growth at a minimum rate of 20 cubic feet per acre/per year, excluding lands withdrawn from timber production by statute or administrative regulation.

Condensing Turbine: A turbine used for electrical power generation from a minimum amount of steam. To increase plant efficiency, these units can have multiple uncontrolled extraction openings for feedwater heating.

Conventional Electricity Generation: Thermal generation of electricity by a plant using coal, petroleum, or natural gas as its energy source, or hydroelectric generation of electricity by a plant using natural stream flow as regulated by available storage. In this report, conventional electricity generation is the direct nonprocess end use that includes fossil fuel used in electric generators for which steam is not an intermediate input. If intermediate energy sources are used, as in cogeneration, the fossil fuel is counted as boiler fuel.

Cord: A stack of wood consisting of 128 cubic feet. A cord has standard dimensions of 4' x 4' x 8' including air space and bark. One cord contains about 1.2 bone dry tons.

Crude Oil: A mixture of hydrocarbons that exists in a liquid state in natural underground reservoirs and remains liquid at atmospheric pressure after passing through separating facilities.

Cull Trees: Live saw-timber and pole-timber size trees which do not contain a merchantable saw-log due to poor form, quality, or undesirable species.

D

Deaeration: Removal of gases from a liquid.

Decoupling: A regulatory design that breaks the link between utility revenues and energy sales to encourage utility investment in conservation.

Densification: A mechanical process to compress biomass (usually wood waste) into pellets, briquettes, cubes, or densified logs.

Diameter at Breast Height (DBH): The diameter of a tree measured 4 feet 6 inches above the ground.

Digester: An airtight vessel or enclosure in which bacteria decomposes biomass in water to produce biogas.

Discount Rate: A rate used to convert future costs or benefits to their present value.

E

Electricity: A form of energy generated by friction, induction, or chemical change that is caused by the presence and motion of elementary charged particles of which matter consists.

Electricity Demand: Electricity demand is the amount of electricity actually consumed onsite, regardless of where or how it was produced. It is a useful measure of electricity consumption without regard to the consumption of other energy sources. Electricity demand is estimated as the sum of electricity purchases, transfers in, and total onsite generation minus the quantities of electricity sold or transferred offsite.

Electric Utility: A legal entity engaged in the generation, transmission, distribution, or sale of electric energy, primarily for use by the public; legally obligated to provide service to the public within its franchised area; and required to file forms listed in the *Code of Federal Regulations*, Title 18, Part 141. Independent power producers and facilities that qualify as cogenerators or small power producers under the Public Utility Regulatory Policies Act are not considered electric utilities.

Emission Credit Trading: A program administrated by the Environmental Protection Agency under which low polluters are awarded credits which may be traded on a regulated market and purchased by polluters who are in noncompliance for emissions until compliance can be achieved.

Emission Offset: A reduction in the air pollution emissions of existing sources to compensate for emissions from new sources.

Energy Crops: Crops specifically bred or genetically engineered and grown for energy applications. It normally does not include typical commodity crops that can also be used for energy (such as corn for ethanol) that are used primarily for non-energy applications.

Energy Facility Siting Council (EFSC): A seven-member council that coordinates and approves siting for power plants, transmission lines, and pipelines in Oregon.

Enzymatic Hydrolysis: A process by which enzymes (biological catalysts) are used to break down starch or cellulose into sugar.

EP Toxicity: A test defined by the federal Environmental Protection Agency to check a substance for the presence of arsenic, barium, cadmium, chromium, lead, mercury, selenium, or silver. 40 CFR 261.24 defines the concentrations constituting hazardous waste and the test procedure.

Ethanol: Ethyl alcohol produced by fermentation and distillation. An alcohol compound with the chemical formula CH_3CH_20H formed during sugar fermentation by yeast. Grain alcohol.

F

Fast Pyrolysis: Thermal conversion of biomass by rapid heating to between 450° to 600°C in the absence of oxygen.

Feedstock: Any material which is converted to another form or product.

FERC: Federal Energy Regulatory Commission.

Firm Power **(Firm Energy):** Power which is guaranteed by the supplier to be available at all times during a period covered by a commitment. That portion of a customer's energy load for which service is assured by the utility provider.

Fluidized-Bed Boiler: A large, refractory-lined vessel with an air distribution member or plate in the bottom, a hot gas outlet in or near the top, and some provisions for introducing fuel. The fluidized bed is formed by blowing air up through a layer of inert particles (such as sand or limestone) at a rate that causes the particles to go into suspension and continuous motion. The super-hot bed material increases combustion efficiency by its direct contact with the fuel.

Fluidized-Bed Burner: A biomass combustor in which a fluidized bed is formed by blowing air up through a layer of inert particles (such as sand or limestone) at a rate that causes the particles to go into suspension and continuous motion. The super-hot bed material increases combustion efficiency by its direct contact with the fuel.

Fly Ash: Small ash particles carried in suspension in combustion products.

Forest Residues: Material not harvested or removed from logging sites in commercial hardwood and softwood stands as well as material resulting from forest management operations such as precommercial thinnings and removal of dead and dying trees.

Fossil Fuel: Solid, liquid, or gaseous fuels formed in the ground after millions of years by chemical and physical changes in plant and animal residues under high temperature and pressure. Oil, natural gas, and coal are fossil fuels.

Fuel: Any substance that can be burned to produce heat or power.

Fuel Cell: A device that converts the energy of a fuel directly to electricity and heat, without combustion.

Fuel Cycle: The series of steps required to produce electricity. The fuel cycle includes mining or otherwise acquiring the raw fuel source, processing and cleaning the fuel, transport, electricity generation, waste management and plant decommissioning.

Fuel-Switching Capability: The short-term capability of a manufacturing establishment to have used substitute energy sources in place of those actually consumed. Capability to use substitute energy sources means the establishment's combustors had the machinery or equipment either in place or available for installation so that substitutions could be introduced without extensive modifications.

G

Gas Turbine (Combustion Turbine): A turbine that converts the energy of hot compressed gases (produced by burning fuel in compressed air) into mechanical power. Often fired by natural gas or fuel oil.

Gasification: A chemical or heat process to convert a solid fuel to a gaseous form.

Gasifier: A device for converting solid fuel into gaseous fuel. In biomass systems, the process is referred to as pyrolitic distillation. See Pyrolysis.

Gasohol: A motor vehicle fuel which is a blend of 90 percent (by volume) unleaded gasoline with 10 percent ethanol.

Generation: The process of producing steam or electrical energy by transforming other forms of energy.

Geothermal Energy: Hot water or steam, extracted from reservoirs in the Earth's crust and supplied to steam turbines that drive generators to produce electricity.

Grate-Fired Burner: A type of combustor in which biomass is burned on grates. These grates can be flat or sloping, stationary or moving. Ash removal from grates may be accomplished by moving arms, steam or air blowing systems.

Green Ton: 2,000 pounds of undried biomass material. Moisture content must be specified if green tons are used as a measure of fuel energy.

Gross Heating Value (GHV): The maximum potential energy in the fuel as received. It reflects the displacement of fiber by water present in the fuel. Expressed as:

$$GHV = HHV\ (1 - MC\ /\ 100)$$

where HHV is the higher heating value and MC is the moisture content.

Growing Stock: The portion from 1-foot stump to a minimum 4.0-inch top diameter of live trees that are at least 5.0 inches in diameter at breast height, of commercially desirable species and quality.

H

Heat Rate: The amount of fuel energy required by a power plant to produce one kilowatt-hour of electrical output. A measure of generating station thermal efficiency, generally expressed in Btu per net kWh. It is computed by dividing the total Btu content of fuel burned for electric generation by the resulting net kWh generation.

Heating Value: The maximum amount of energy that is available from burning a substance.

Higher Heating Value (HHV): The maximum potential energy in dry fuel. For wood, the range is 7,600 to 9,600 Btu/lb.

Hog Fuel (Hogged Fuel): Wood residues processed through a chipper or mill to produce coarse chips normally used for fuel. Bark, saw-dust, planer shavings, wood chunks, dirt, and fines may be included.

Hydrocarbon: Any chemical compound containing hydrogen, oxygen, and carbon.

Hydroelectric Power: Electricity generated by a turbine driven by falling water.

I

Incinerator: Any device used to burn solid or liquid residues or wastes as a method of disposal. In some incinerators, provisions are made for recovering the heat produced.

Incremental Energy Costs: The cost of producing and transporting the next available unit of electrical energy. Short run incremental costs (SRIC) include only incremental operating costs. Long run incremental costs (LRIC) include the capital cost of new resources or capital equipment.

Independent Power Producer: A power production facility that is not part of a regulated utility.

Indirect Liquefaction: Conversion of biomass to a liquid fuel through a synthesis gas intermediate step.

Investment Tax Credit: A specified percentage of the dollar amount of certain new investments that a company can deduct as a credit against its income tax bill.

Investor-Owned Utility: (IOU) A private power company owned by and responsible to its shareholders and regulated by a public service commission.

J

Joule (J): This is a unit of energy, including both work and a quantity of heat. There are approximately 1,055 joules in a BTU and 3.6 million joules in a kilowatt-hour.

K

Kiln (Dry Kiln) : A chamber in which wood products are seasoned by applying heat and withdrawing moist air.

Kilowatt (kw): A measure of electrical power equal to 1,000 Watts. 1 kW = 3,413 Btu/hr = 1.341 horsepower.

Kilowatt Hour (kwh): A measure of energy equivalent to the expenditure of one kilowatt for one hour. For example, 1 kWh will light a 100-watt light bulb for 10 hours. 1 kWh = 3,413 Btu.

Knutson-Vandenberg Act (KV): Federal law that allows the U.S. Forest Service to collect money from a timber sale for resource enhancement, protection, and improvement work in the timber sale vicinity.

L

Landfill Gas: A biogas that is generated by decomposition of organic material at landfill disposal sites. Landfill gas is approximately 50 percent methane.

Large Woody Debris: Dead woody material greater than 20" in diameter on the ground or in a stream or river. It may consist of logs, trees, or parts of trees. Large woody debris contributes to long-term site productivity and health in several ways. It supplies nutrients to the soil, supports symbiotic fungi that are beneficial to conifers, and provides habitat beneficial for rodents and insects.

Lignin: An amorphous polymer related to cellulose that together with cellulose forms the cell walls of woody plants and acts as the bonding agent between cells.

Liquefaction: The process of converting biomass from a solid to a liquid. The conversion process is a chemical change that takes place at elevated temperatures and pressures.

Liquid Hydrocarbon: One of a very large group of chemical compounds composed only of carbon and hydrogen. The largest source of hydrocarbons is petroleum.

Load: (1) The amount of electrical power required at a given point on a system. (2) The average demand on electrical equipment or on an electric system.

Logging Residues: The unused portion of wood and bark left on the ground after harvesting merchantable wood. The material may include tops, broken pieces, and unmerchantable species.

Long Ton: (shipping ton) 2,240 pounds. Commonly used in Great Britain.

Lower Heating Value (LHV): The potential energy in a fuel if the water vapor from combustion of hydrogen is not condensed.

Lowest Achievable Emissions Rate (LAER): Used to describe air emissions control technology. A rate of emissions defined by the permitting agency. LAER sets emission limits for non-attainment areas.

M

Mass Burn Facility: A facility in which the pretreatment of MSW includes only inspection and simple separation to remove oversized, hazardous, or explosive materials before combusting. Large mass burn facilities have capacities of 3000 tons of MSW per day or more. Modular plants with capacities as low as 25 tons per day have been built. Mass burn technologies represent over 75% of all the MSW-to-energy facilities constructed in the United States to date. The major components of a mass burn facility include refuse receiving and handling, combustion and steam generation, flue gas cleaning, power generation, condenser cooling water, residue hauling, and storage.

MBF: One thousand board feet of lumber.

MC: See Moisture content.

MCF: Thousand cubic feet.

Megawatt (MW): The electrical unit of power that equals one million Watts (1,000 kW).

Merchantable: Logs from which at least some of the volume can be converted into sound grades of lumber (“standard and better” framing lumber).

Methane: An odorless, colorless, flammable gas with the formula CH_4 that is the primary constituent of natural gas and biogas.

Methanogen: A methane-producing organism.

Methanol: Methyl alcohol having the chemical formula CH_30H. Methanol is usually produced by chemical conversion at high temperatures and pressures. Wood alcohol. Although usually produced from natural gas, methanol can be produced from gasified biomass (syngas).

Metric Ton: (or tonne) 1000 kilograms. 1 metric ton = 2,204.62 lb = 1.023 short tons.

Mill Residue: Wood and bark residues generated by processing logs into lumber, plywood, and paper.

MMBF: One million board feet (lumber).

MMBtu: One million British thermal units.

MMCF: One million cubic feet.

Municipal Solid Waste (MSW) : Garbage. Refuse offering the potential for energy recovery; includes residential, commercial, and institutional wastes.

N

National Ambient Air Quality Standards (NAAQS): Federal standards established by the Clean Air Act.

National Environmental Policy Act (NEPA): A federal law enacted in 1969 that requires all federal agencies to consider and analyze the environmental impacts of any proposed action. NEPA requires an environmental impact statement for major federal actions significantly affecting the quality of the environment. NEPA requires federal agencies to inform and involve the public in the agency's decision making process and to consider the environmental impacts of the agency's decision.

Natural Gas: A mixture of hydrocarbon compounds and small quantities of various non-hydrocarbons existing in the gaseous phase or in solution with crude oil in natural underground reservoir conditions.

Net Heating Value (NHV): The potential energy available in the fuel as received, taking into account the energy loss in evaporating and superheating the water in the sample. Expressed as: NVH = (HHV x (1- MC / 100)) - (LH(2)O x MC / 100).

Net Present Value: The sum of the costs and benefits of a project or activity. Future benefits and costs are discounted to account for interest costs.

Nonutility Power Producer: A legal entity that owns electric generating capacity and is not an electric utility. Includes qualifying cogenerators, qualifying small power producers, and other nonutility generators (including independent power producers) with a franchised area and not required to file forms listed in the *Code of Federal Regulations*, Title 18, Part 141.

NO_x Emission: An airborne emission of oxides of nitrogen during biomass combustion, including thermal NO_x that is formed from nitrogen in the combustion air, and fuel NO_x comes from oxidation of reduced forms of nitrogen contained in the fuel.

O

Oven-Dry Ton: 2,000 pounds of material dried to a zero moisture content. A standard measure for quantifying biomass.

P

Particulate: A small, discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions. Particulates take the form of aerosol, dust, fume, mist, smoke, or spray. Each of these forms has different properties.

Particulate Emissions: Fine liquid or solid particles discharged with exhaust gases. Usually measured as grains per cubic foot or pounds per million Btu input.

Photobiological Conversion Process: An alternative biological process for solar energy conversion which first appeared in the early 1970's. This is a process that produces hydrogen gas from water using photosynthetic apparatus of green plants and algae.

Process Heat: Heat used in an industrial process rather than for space heating or other house-keeping purposes.

Producer Gas: Fuel gas high in carbon monoxide (CO) and hydrogen (H_2), produced by burning a solid fuel with insufficient air or by passing a mixture of air and steam through a burning bed of solid fuel.

Propane: A normally gaseous, straight chain, paraffinic hydrocarbon (C_3H_8) extracted from natural gas or refinery gas streams.

Proximate Analysis: An analysis which reports volatile matter, fixed carbon, moisture content, and ash present in a fuel as a percentage of dry fuel weight.

Public Utility Regulatory Policies Act (PURPA): A federal law requiring a utility to buy the power produced by a qualifying facility at a price equal to that which the utility would otherwise pay if it were to build its own power plant or buy power from another source.

Pulp Chips: Timber or residues processed into small pieces of wood of more or less uniform dimensions with minimal amounts of bark.

Pulping Liquor (Black Liquor): The alkaline spent liquor removed from the digesters in the process of chemically pulping wood. After evaporation, the liquor is burned as a fuel in a recovery furnace that permits the recovery of certain basic chemicals.

Pyrolysis: The thermal decomposition of biomass at high temperatures (greater than 400° F, or 200° C) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Q

Quad: One quadrillion Btu (10^{15}Btu). An energy equivalent to approximately 172 million barrels of oil.

Qualifying Facility: A power production facility that qualifies for special treatment under the Public Utility Regulatory Policies Act. A qualifying facility must generate its power using cogeneration, biomass, waste, geothermal energy, or renewable resources, such as solar and wind. PURPA prohibits utilities from owning majority interest in qualifying facilities.

R

Recovery Boiler: A pulp mill boiler in which lignin and spent cooking liquor (black liquor) is burned to generate steam.

Refuse-Derived Fuel (RDF): Fuel prepared from municipal solid waste. Noncombustible materials such as rocks, glass, and metals are removed, and the remaining combustible portion of the solid waste is chopped or shredded. RDF facilities process between 100 and 3000 tons of MSW per day.

Regeneration Harvest: A timber harvest method that removes selected trees in the existing stand to a density that allows for the establishment of a new even-aged stand below.

Renewable Energy: An energy resource replenished continuously or that is replaced after use through natural means. Sustainable energy. Renewable energy resources include bioenergy, solar energy, wind energy, geothermal power, and hydropower.

Retrofitting: The application of conservation, efficiency, or renewable energy technologies to existing structures.

Return on Investment (ROI): The interest rate at which the net present value of a project is zero. Multiple values are possible.

Rough Trees: Live trees of commercial species which do not contain a sawlog because of roughness, poor form, splits, or cracks. Includes all living trees of noncommercial species.

S

Salvage Logging: The harvest of dead, dying, damaged, or weak trees to prevent the spread of disease or insects and to reduce the risk of high intensity fire.

Saturated Steam: Steam at the temperature that corresponds to its boiling temperature at the same pressure.

Sawdust: Small particles of wood removed by the saw in cutting.

Sawlog: A log meeting minimum commercial requirements of diameter, length, and defect. The usual commercial requirements are a minimum of 8' long with an inside bark diameter of 6" for softwoods and 8" for hardwoods.

Sawtimber: Live trees of commercial species containing at least one 12' sawlog or two noncontiguous 8' logs. Softwoods must be at least 9" in diameter and hardwoods at least 11" in diameter.

Shaving: A very thin slice of wood produced in planing lumber, or by a specialized shaving machine.

Short Rotation Energy Plantation: Woody energy crops which are established and managed under short-rotation intensive culture practices. These plantations are managed for maximum biomass yield.

Short Ton: 2000 pounds. A ton, as commonly used in the U.S. and Canada.

Slash: The unmerchantable material left on site subsequent to harvesting a timber stand, including tops, limbs, cull sections.

Slow pyrolysis: Thermal conversion of biomass to fuel by slow heating to less than 450 °C in the absence of oxygen.

Sludge (or Sewage Sludge or Biosolids): The mixture of organic and inorganic substances separated from sewage.

Solar Energy: The radiant energy of the sun that can be converted into other forms of energy, such as heat or electricity.

Stand (tree stand, timber stand): A community of trees managed as a unit. Trees or other vegetation occupying a specific area, sufficiently uniform in species composition, age arrangement, and condition as to be distinguishable from the forest or other cover on adjoining areas.

Stand Density: The number or mass of trees occupying a site. It is usually measured in terms of stand density index or basal area per acre.

Steam Conversion Factors (approximations):
1 pound of steam = 1,000 Btu = .3 kW. 10,000 lbs/hr steam = 300 boiler horsepower.

Steam Turbine: A device for converting energy of high-pressure steam (produced in a boiler) into mechanical power which can then be used to generate electricity.

Stumpage: (1) Standing live or dead uncut trees. (2) The value or rate paid to purchase standing trees for harvest.

Sunk Cost: A cost already incurred and therefore not considered in making a current investment decision.

Superheated Steam: Steam at a given pressure which is above the temperature which corresponds to boiling temperature at that given pressure.

Suspension Burner: A special purpose combustor for the combustion of biomass fuels. They require dry and finely divided fuel particles which are suspended by applying either a negative or positive pressure.

Standard Cubic Foot (scf): The standard unit of volume for measuring natural gas, a cubic foot at a base of 14.73 pounds per square inch at 60 degrees Farenheit. A scf of natural gas equals approximately 1,027 Btu.

Syngas: A synthetic gas produced through gasification of biomass. Syngas is similar to natural gas, but with a lower Btu content, and can also be cleaned and conditioned to form a feedstock for the production of methanol.

T

Therm: A unit of energy equal to 100,000 Btus; used primarily for natural gas.

Thermal Resource: A facility that produces electricity by using a heat engine to power an electric generator. The heat may be supplied by the combustion of coal, oil, natural gas, biomass, or other fuels, including nuclear fission, solar, or geothermal resources.

Thermochemical Conversion Process: Chemical reactions employing heat to produce fuels.

Timberland: Forest land capable of producing 20 cubic feet of wood per acre per year.

Tipping Fee: A fee for disposal of waste.

Topping Cycle: A cogeneration system in which electric power is produced first. The reject heat from power production is then used to produce useful process heat.

Transmission: The process of long-distance transport of electrical energy, generally accomplished by raising the electric current to high voltages.

Turbine: A machine for converting the heat energy in steam or high temperature gas into mechanical energy. In a turbine, a high velocity flow of steam or gas passes through successive rows of radial blades fastened to a central shaft.

U

Urban Growth Boundary: A land use boundary surrounding a city. Urban land uses are permitted within the urban growth boundary.

V

Valley Segment: That portion of a stream network with similar morphologies and governing geomorphic processes identified by valley bottom and sideslope geomorphic characteristics.

Volatile Organic Compounds (VOC): Emissions of non-methane hydrocarbons, measured by standard DEQ methods.

W

Waste Streams: Unused solid or liquid by-products of a process.

Watershed: The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake.

Watt: The common base unit of power in the metric system. One watt equals one joule per second, or the power developed in a circuit by a current of one ampere flowing through a potential difference of one volt. One Watt = 3.413 Btu/hr.

Wetlands: Lands where saturation with water is the primary factor determining soil development and the kinds of plant and animal communities living on or under the surface.

Whole-Tree Chips: Chips made from entire trees, including small branches. The operation of converting whole trees to chips is usually carried out in the woods or near the cutting area and the chips are blown into a truck for transportation to a mill for further processing.

Wind Energy: Energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

Wood Energy: Wood and wood products used as fuel, including roundwood, limb wood, wood chips, bark, sawdust, forest residues, charcoal, pulp waste, and spent pulping liquor.

Wood Waste: Wood byproducts used as a fuel. Included are limb wood, wood chips, bark, sawdust, forest residues, manufacturing residues, and pulp waste.

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